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DEPARTMENT OF MINES
Hon. LOUIS CODERRE, Minister A. P. LOW, Deputy Minister
GEOLOGICAL SURVEY
R. W. BROCK, Director.

GUIDE BOOK No. 8

Transcontinental Excursion C1

Toronto *to* Victoria *and return* *Via* Canadian Pacific *and* Canadian Northern Railways

PART I

OTTAWA
GOVERNMENT PRINTING BUREAU
1913

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PART I

ISSUED BY THE GEOLOGICAL SURVEY

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TORONTO TO SUDBURY.

Between Toronto and Sudbury the route of Excursion C 1 follows that of A 3, a description of which is contained in Guide Book No. 6. The nickel-copper deposits of Sudbury are described in the same guide book.

SUDBURY TO CARTIER.

BY

A. P. COLEMAN.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. **Sudbury**—Altitude 850 ft. (260 m.). From Sudbury the main line of the Canadian Pacific railway ascends through hills of arkose, quartzite, greenstone and granite to the margin of the nickel-bearing eruptive sheet at Murray mine (Alt. 992 ft.,) (302·3 m.), where the gossan covering the nickel ore of the mine is widespread. The old smelter, now in ruins, stands just to the south of the railway. From this point the line descends toward Azilda, passing for two or three miles (3·2 or 4·8 km.) over gray norite, the nickel-bearing rock, which insensibly passes into flesh-colored micro-pegmatite ending on a hill a little to the west of Azilda. Whitewater lake may be seen to the south.

7 m. 11 km. **Azilda**—Altitude 881 ft. (268·5 m.). From Azilda the route leads westward for 14 miles (12·5 km.) through a flat plain of stratified clay formed in old Lake Algonquin. Above the plain rise a few dome shaped hills of gray Upper Huronian sandstone at Chelmsford and Larchwood. The railway crosses Vermilion river at the latter point.

21 m. 33·7 km. **Larchwood**—Altitude 868 ft. (264·5 m.). From Larchwood westward the road begins to ascend once more over delta sands and

Miles and Kilometres.

gravels of the ancient lake to Phelan, where the railway follows up Onaping river through rough hills of Upper Huronian tuff and conglomerate to the micropegmatite on the northwestern side of the nickel basin. For four miles (6·4 km.) the road passes between high hills belonging to the nickel eruptive, and then enters the Laurentian at Windy Lake, which lies to the south.

32 m. 51·4 km. **Windy Lake**—Altitude 1,221 ft. (372 m.). Beyond this to Cartier the landscape consists of hills of granite and gneiss, partially covered with sand and gravel deposits of Lake Algonquin.

CARTIER TO COLDWELL.

BY

A. L. PARSONS.

INTRODUCTION.

The region traversed by the Canadian Pacific railway from Cartier to the boundary between Ontario and Manitoba is underlain by Pre-Cambrian rocks of Laurentian, Keewatin, Lower Huronian, Animikie (Upper Huronian) and Keweenawan age. These solid rocks are very thinly covered by Pleistocene glacial deposits and stratified sands, gravels and clays. Their uneven surface contains unnumbered lakes and numerous rivers, which constitute the principal avenues of communication with the region at a distance from the railway. Along the north shore of Lake Superior the country has a different aspect, where the Animikie and Keweenawan are present. Most of the region is covered with a thick growth of forest.

ANNOTATED GUIDE.

Miles and Kilometres.

38 m. **Cartier**—Altitude 1,364 ft. (415·7 m.).
61 km. Leaving Cartier, the first three miles (4·8 km.) is over typical Laurentian granite and gneiss. Near Geneva is a contact with Keewatin, and for about 10 miles (16 km.) most of the rock is of the typical Keewatin traps, in some instances highly altered. This rock again gives place to the Laurentian $12\frac{1}{2}$ miles (20·1 km.) west of Cartier, and with two exceptions the Laurentian continues uninterrupted to Chapleau, the next divisional point. The two Keewatin outcrops visible in this distance are between Roberts and Ramsay.

109 m. **Ramsay**—Altitude 1,403 ft. (427·6 m.).
176 km.

176 m. **Chapleau**—Altitude 1,418 ft. (432·2 m.).
283 km. The rock between Chapleau and White River are mainly Laurentian and exhibit the typical rounded hills formed by glaciation, the valleys between which frequently contain lakes and swamps. Four Keewatin areas are crossed in this interval. The first of these is about two miles wide (3·2 km.) and is first seen $9\frac{1}{2}$ miles (15·3 km.) west of Chapleau. The second and third are probably connected, though on the railroad they are separated by a band of Laurentian about three miles (4·8 km.) wide. These exposures are about equal in width, and the first of them extends from
236 m. $42\frac{1}{2}$ miles (68·4 km.) west of Chapleau,
380 km. the milepost 58, and the third one begins one mile (1·6 km.) west of **Missinaibi** and extends for $11\frac{1}{2}$ miles (18·5 km.). The fourth is a small outcrop one mile (1·6 km.) west of Williams.

307 m. **White River**—Altitude 1,230 ft. (374·9 m.).
494 km. At White River, a divisional point on the railway, yards have been built for feeding and resting cattle in transit.

Miles and Kilometres.

Beyond White River for 20 miles (32·2 km.) is a granitic region, largely covered with sand, beyond which the Keewatin again appears and continues with slight interruptions to Peninsula, where the remarkable series of laurvikite, syenites and nepheline syenites of the Port Coldwell region begin. From this point the scenery changes from the diversified cliffs on the north and the broad expanse of Lake Superior to the south.

382 m. 615 km. **Coldwell**— Several short tunnels cut through buttress-like projections of the rock masses. The nepheline syenite series extends from near Peninsula to Middleton.

THE NEPHELINE AND ALKALI SYENITES OF THE PORT COLDWELL AREA.

BY

A. E. Barlow.*

INTRODUCTION.

Location and Size of Area.

The Port Coldwell area of nepheline and alkali-syenites is situated on the northeast side of Lake Superior, extending from a point on the Canadian Pacific Railway nearly two miles (3·2 km) east of Peninsula station to another point on the same railway a short distance west of Middleton The area underlain by these rocks, including the shore line and offlying islands, is a little over 15 miles (24 km) from east to west. The necessary curves, in following the sinuosities of the coast line of the lake, have increased the distance along the railway to about 21 miles (33·7 km). Its northern boundary is believed never to be more than 10 miles (16 km.) from the shore or railway. The total area underlain by these rocks is probably about 100 square miles (259 sq. km.)

* Synopsis of paper by H. L. Kerr, Toronto, Canada.

History of Investigation.

The presence of nepheline in the vicinity of Port Coldwell was known very early in the geological investigation of Canada, and some details respecting its mode of occurrence are included in the Report of Progress of the Geological Survey of Canada for 1846-47 (**1**), as also in the Geology of Canada 1863 (**2**). Attention was directed to these early descriptions through the discovery in 1898 by Dr. A. P. Coleman of the University of Toronto of a dyke rich in analcite, near Heron Bay, for which rock he proposed the name "heronite". Subsequently it was shown that "heronite ' was really a decomposed tinguaite (**3, 4, 5, 6**).

In 1900 Dr. Frank D. Adams of McGill University, furnished under the title "On the Probable Occurrence of a Large Area of Nepheline-bearing Rocks on the Northeast Coast of Lake Superior" (**7**), a detailed petrographical description of four thin sections prepared from two rock specimens collected from the vicinity of Peninsula harbour by Peter McKellar in 1870 and Dr. Selwyn in 1882. During the summer of 1900, Dr. Coleman again visited Heron bay, but although successful in discovering certain dykes rich in nepheline, he failed to locate any large area of rocks containing this mineral.

In 1901 another examination was made, during which outcrops of nepheline and other closely related alkaline syenites were revealed between Peninsula harbour and Middleton station (**8**) on the Canadian Pacific railway.

In 1902 Dr. T. L. Walker of the University of Toronto spent a few days collecting museum specimens in this neighbourhood. At his suggestion Mr. H. L. Kerr of the same institution undertook a petrographical study of the specimens then collected, as well as of those obtained by Dr. Coleman, with a view of making a more detailed examination of the whole Port Coldwell area (**9**).

During the fall of 1906 and again in 1907, Mr. Kerr spent about ten weeks in all in the field gathering information regarding the extent of country covered by the several varieties of these syenites. Mr. Kerr's examinations and descriptions have evidently been made with great care and in such detail as to make possible a rather complete and satisfactory statement of this interesting complex of igneous rocks.

Topography.

The Port Coldwell region is exceedingly rough and rocky, consisting of high rounded hills scantily covered with soil or drift material, and therefore easy of geological examination. The central part is in general of higher altitude than the remainder, gradually sloping both to the east and west. The highest point is a hill on Pic island which, according to aneroid determination is 850 feet (259 m.) above the lake. In the vicinity of Red Sucker and in the Coldwell peninsula some of the elevations vary from 250 to 700 feet (76 to 213 m) above the lake,* Fires have destroyed most of the forest in the vicinity of the railway.

GEOLOGY OF THE AREA.

General Relationships.

It is impossible as well as unnecessary to describe in detail the mineralogical composition of all the varieties of these syenites, for as usual their extreme and rapid variation in this respect is one of the most noteworthy features of their development. They are all, however, differentiation products of a highly alkaline magma representing one phase of plutonic intrusion. Although for purposes of description they may be considered as divisible into seven groups, it must be understood that no natural line exists between these respective subdivisions.

1. Quartz syenite.
2. Red hornblende syenite.
3. Augite syenite (laurvikite).
4. White syenite.
5. Nepheline syenite.
6. Essexite, olivine gabbro and picrite.
7. Camptonite.

Petrographic Descriptions of Chief Types.

Quartz syenite.—Quartz syenite is perhaps the least important of these groups, for it is a comparatively rare

* The mean water level of Lake Superior (1871-1900) was 601.7 feet (183.38 m.) above mean tide level.

(quartziferous) variety of both the red hornblende syenite and the augite syenite or laurvikite. It is medium grained, of a dark red colour, in places assuming a distinct greenish tinge. It is typically developed in the vicinity of Red Sucker. The feldspar is a cryptoperthitic growth of orthoclase and albite. Green hornblende, often much fractured and decomposed, is the prevailing coloured constituent. Occasionally there is a very little biotite. Quartz occurs in very small amount, both free and graphically intergrown with the feldspar. Magnetite, resulting from the decomposition of the hornblende, is usually abundant. Apatite, fluorite, pyrite, and secondary calcite, the accessory minerals, are sparingly represented.

Red hornblende-syenite.—The red hornblende syenite is perhaps the most important of the subdivisions mentioned for, from the field work so far accomplished, it seems to cover the largest area. The deep red colour of the very abundant feldspar, in contrast with the dark green of the greatly subordinate hornblende, gives the rock a pleasing and conspicuous appearance. It is usually intimately associated with the darker coloured augite syenite, into which it differentiates by insensible gradations. This scarcely perceptible transition is well illustrated by exposures north of Peninsula harbour and along the railway between Coldwell and Middleton. Pegmatitic phases, in comparatively narrow dyke-like forms, intersect the associated rocks and are present in the midst of the parent plutonic mass. The rock is composed mainly of feldspar (orthoclase and microperthite) and hornbelnde. This hornblende, which is a variety closely related to barkevikite with strong pleochroism in colours ranging from light yellowish green to chestnut brown, is always in subordinate amount, especially in coarse-textured varieties. Pyroxene (diopside) rarely occurs except as a kernel in the centre of the hornblende individuals. Biotite is usually present in very small quantities. Sphene of characteristic shape, apatite in comparatively large crystals, and magnetite, as accessory minerals, complete the list of constituents.

Augite syenite.—The dark coloured augite syenite, which occupies so large an area in the vicinity of Peninsula, is one of the most interesting of the rock-types represented in this district. It varies in colour from dark brownish-grey to almost black. Transitional phases are dull

reddish-grey or soapy brown. Freshly broken surfaces exhibit the brightly gleaming surfaces of plate-like or lath-shaped feldspar. These idiomorphic feldspars are frequently Carlsbad twins, often with a handsome bluish shimmer. The feldspars are greatly predominant, but, owing to their prevailing dark colour, which is due to inclusions, the relative paucity of bisilicate material is not noticeable except upon close inspection. The rock is coarse in texture, the feldspars averaging a quarter of an inch ((·6 cm.) in length and breadth, but only a tenth of an inch (·25 cm.) in thickness.

The mineral constituents are principally feldspar and pyroxene with subordinate amounts of hornblende, biotite and olivine; magnetite, apatite and pyrite are accessory constituents. The feldspar is for the most part a microperthitic intergrowth of albite and orthoclase, although natron-orthoclase, orthoclase and plagioclase are also present, but are relatively unimportant. Pyroxene is the characteristic dark mineral. In the Peninsula area this mineral shows a pale brown interior with a deep green border, and is undoubtedly one of the aegirine-augite series. In outcrops, near Coldwell as well as between the crossing of Little Pic river and Middleton station, the augite is pale violet, sometimes bordered by brown barkevikite. In the western part of the Peninsula area the pyroxene is commonly diopside, frequently surrounded by a border of brown barkevikite and bright blue arfvedsonite. Olivine is usually present but is not an abundant constituent except in the vicinity of Middleton. The rock in the cutting east of Penisnula near Craig's gravel pit contains an olivine which, between crossed nicols, resembles sphene. It was identified by Brögger, who states that it corresponds very closely with the olivine present in the laurivikite of southern Norway. Hornblende, usually barkevikite, occurs sparingly. Arfvedsonite is also noticeable, and very occasionally riebeckite, distinguished by its pleochroism in deep bluish colours. Biotite is an unimportant constituent. Magnetite, pyrite, apatite, and bluish fluorite are the accessory constituents present.

White feldspathic variety.—The white feldspathic variety, which is closely related to the nepheline syenite occurs about the centre of Big Pic island. The white feldspar, which is by far the most abundant mineral, is chiefly orthoclase or albite or graphic intergrowths of these.

The chief of the dark coloured constituents, which are usually grouped together, is a very deep brown hornblende. A few scales of muscovite and rare fragments of pyroxene enclosed in hornblende were noticed. Magnetite and apatite are conspicuous associates of the hornblende and biotite. Nepheline, usually decomposed to hydronephelite. is sometimes present in very small amount.

Nepheline syenite.—The nepheline syenite may in a general be described as a medium grained rock of granitic habit varying from pale grey to dark grey in colour. Many outcrops are pinkish or purplish owing to the relative abundance of hydronephelite, a decomposition product of the nepheline. When present in very considerable amount, as is often the case, it produces a striking and beautiful rock. Gneissoid structure is very uncommon, but occasionally a peculiarly banded structure, due to the segregation chiefly of the darker coloured minerals, is in evidence. Weathered surfaces are characteristically pitted owing to the rapidity with which nepheline decomposes.

The most abundant mineral constituent is feldspar. Nepheline sometimes constitutes one-sixth of the whole rock mass (hill east of Coldwell station). Hydronephelite is always present, while hornblende and magnetite and the less abundant pyroxene are also readily distinguishable. In most instances the coloured constituents are very subordinate, but in some cases they form the bulk of the rock.

All the feldspars belong to the natron-orthoclase-microperthite series. All gradations from undoubted pure natron-orthoclase to distinct microperthitic intergrowths of orthoclase and albite are found. Nepheline is always the last mineral constituent to crystallize, occupy ing the irregular interspaces between the other constituents. As a rule it is usually decomposed in part, or altogether, to hydronephelite. This orange-red hydronephelite is the most striking mineral constituent of the nepheline syenite. It is undoubtedly the orange-coloured nepheline of the original descriptions by Logan. This mineral is very abundant and characteristic. It occurs both in simple individuals, often of microscopic dimensions and sometimes with centres of unaltered nepheline still remaining, and also in aggregates of several individuals up to half an inch (1·27 cm.) or even more in diameter.

Sodalite is almost entirely absent from the nepheline syenites of this area. It does occur, however, in the highest hill southwest of Coldwell, on Pic island and about two miles (3·2 km.) north of mile post 78.

Hornblende is much the most abundant ferromagnesian constituent. There is a green and a brown variety. The optical properties of the brown hornblende suggest barkevikite, although no confirmatory chemical analysis was undertaken. The colouring of the individuals is by no means uniform, but pale interiors with deeply coloured borders are the rule; often the crystals have a spotted appearance. Pleochroism is very marked, varying from greenish yellow to chestnut brown in the brown variety, and in the green hornblende from straw yellow to deep green. Poikilitic structure mainly with feldspar is common. Pyroxene, ranging in composition from deep green aegirine-augite to pale coloured diopside, and often surrounded by a border of hornblende is usually present even in specimens that are rich in hornblende. The pleochroism of the aegirine-augite is very strong and from yellow to grass green. Aegirine-augite is especially characteristic of varieties rich in nepheline. Frequently it forms a rim around the paler coloured diopside. Biotite is by no means a common constituent, although in one locality (west part of Coldwell peninsula) it is the chief ferromagnesian mineral. Magnetite as an inclusion is always present, and comparatively large apatite crystals are common. Occasionally muscovite, sphene, pyrite and purple fluorite are noticeable.

Essexite, Olivine Gabbro and Picrite.—The basic rock of the Coldwell massif are undoubtedly the oldest of the series. They are very variable in composition. The more common type seen in the neighborhood of Coldwell is a dark grey rock of medium texture with gleaming crystals of biotite. The dark coloured constituents represent more than three-fourths of the whole rock mass. Thin sections show augite, olivine, biotite, hornblende, labradorite, some orthoclase, occasionally nepheline and much magnetite with apatite as the chief accessory constituent.

Most of the dykes of the region are small, ranging from a couple of inches (5 cm.) to four feet (1·2 m) in width. They are usually of a slate grey colour and very fine grained. Many of them are intermediate in composition between

camptonite and essexite. The camptonites are the principal dykes of the area. They are composed chiefly of hornblende, biotite, feldspar, magnetite, some pyrite, very little apatite and secondary calcite.

RELATIVE AGES OF CHIEF TYPES.

According to Brgöger, the rocks of the Norwegian syenite area were derived from a common magma basin, through a succession of irruptions beginning with the basic rocks and forming a continuous series to the most acid granites. He also states his belief that the later basic dykes found cutting the main rock mass represent the final depletion of the original magma basin. According to Kerr, the oldest rocks of the Port Coldwell complex are the basic picrites, olivine gabbros and essexites; while as in Norway, the youngest rocks of the region are the narrow basic dykes, camptonites, etc. Next in order of age to the oldest basic intrusives are the augite syenite or laurivikite, the red hornblende syenite, and the nepheline syenite.

The difficulties of assigning a definite succession, for the whole area can be understood only by those who have made the attempt in other districts. To the writer of this account, which is an epitomized statement of Kerr's conclusions, it seems that the general succession proceeding from the oldest to the youngest was as follows:—

1. Picrite, olivine gabbro and essexite.
2. Augite syenite or laurivikite.
3. Nepheline syenite.
4. Red hornblende syenite
5. Quartz syenite.
6. Camptonites, etc.

These syenites are all intrusive into the greenstones and greenstone schists of the Keewatin and, so far as can be judged, merge without any sharp line of delineation into granites usually classified as Laurentian.

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COLDWELL TO PORT ARTHUR.

BY

A. L. Parsons.

ANNOTATED GUIDE. (Coldwell to Loon).

Miles and Kilometres from Sudbury.

391 m. 629 km. **Middleton**—Altitude 691 ft. (210·6 m.). From Middleton the railway passes through a region underlain by Keewatin rocks, which extends to Jackfish, a fishing village on Lake Superior.

407 m. 658 km. **Jackfish**—Altitude 632 ft. (192·6 m.). Near Jackfish station the contact of the Keewatin

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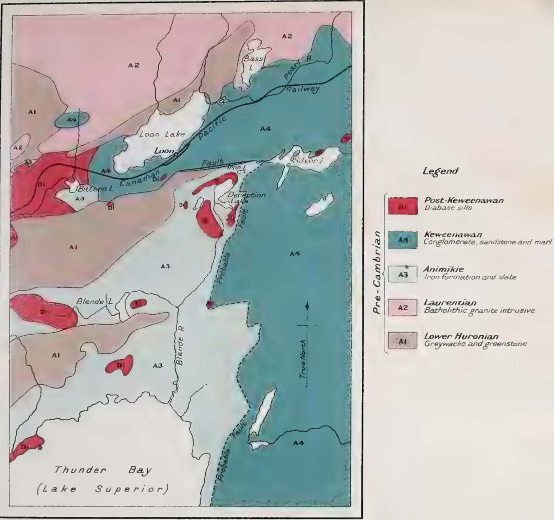

Geological Survey, Canada.

Loon Lake

Miles: 1 ¾ ½ ¼ 0 1 2

Kilometres: 1 ½ 0 1 2 3 4 5

Miles and Kilometres.

and Laurentian is seen. The interval between this station and Schreiber is occupied entirely by Laurentian rock.

426 m. 688·5 km. **Schreiber**—Altitude 993 ft. (302·6 m.). Keewatin trap extends with some interruptions for about five miles (8·0 km.) west of Schreiber, after which the Laurentian and Pleistocene gravel deposits extend almost uninterruptedly to Hartley, where the Animikie is first seen.

From Hartley most of the rock exposures as far as Port Arthur are of Animikie and Keweenawan, with underlying Laurentian bosses. Occasionally Keewatin rocks are present, but these are a minor feature. Many gravel deposits, exhibiting cross-bedding, occur. The best views of the Animikie and Keweenawan rocks are obtained near Kama, Nipigon and Red Rock.

489 m. 787 km. **Nipigon**—Altitude 681 ft. (207·5 m).

531 m. 854·5 km. **Loon**—Altitude 1,000 ft. (304·8 m.).

THE PRE-CAMBRIAN GEOLOGY OF LOON LAKE DISTRICT.

Introduction.

The region around Thunder bay was first described geologically in a brief report by Sir W. E. Logan, (**1**), who also gave a more extended description of the rocks at a later date (**2**) and mapped the formations as they were then known(**3**). Dr. R. Bell (**4**) explored much of this region in 1869 and described many of the rocks. He also prepared a map on which, however, geological boundaries are lacking. The first report accompanied by a detailed map was prepared by E. D. Ingall (**5**), who not only described quite minutely the silver-bearing rocks of the region, but gave a description of the silver mines. Later the investigation of the iron ores of this region was taken up by W. N. Smith (**6, 7**) upon whose work the following classification of the rocks is based.

Pleistocene..................	Glacial drift.
Unconformity.	
Keweenawan (Nipigon).....	Conglomerate, sandstone, marl; diabase sills.
Unconformity.	
Upper Huronian (Animikie) .	Iron-bearing formation and black slates.
Unconformity.	
Lower Huronian............	Greywacke, greenstone, granite.
Unconformity.	
Keewatin..................	Green schists, greenstones, mashed porphyries.

Mr. Smith's article in the Bureau of Mines report was unaccompanied by a map, though one was published in the Mining World and was used with minor changes by L. P. Silver the next year in his report on the Animikie iron rangs (**8**). In accordance with the findings of the Special Committee on the Lake Superior region (**9**) Mr. Silver altered the legend given by Mr. Smith, so that his interpretation of the geological sequence is as follows:—

Pleistocene..................	Glacial drift, residual clays, beach sands and gravel.
Unconformity.	
Logan Sills..................	Diabase, diorite or gabbro intruding all the following formations.
Igneous contact.	
Keweenawan (Nipigon).....	Conglomerate, sandstone, impure marls.
Unconformity.	
Upper Huronian (Animikie)..	Iron - bearing formation, black slates, impure limestone and quartz conglomerate.
Unconformity.	
Middle Huronian...........	Granite (igneous contact).
Lower Huronian............	Conglomerate, greywacke, greenstone, quartz porphyry, amphibolite.
Unconformity.	
Keewatin..................	Quartz porphyry.

The map accompanying Mr. Silver's report has been used in the preparation of the accompanying sketch map

though the correctness of certain portions of it may be questioned. To the writer it would seem that a considerable portion of the rock mapped as Lower Huronian should be included in the Keewatin, particularly that situated about one half mile south of Loon station, near Wylie's camp. The age of the granite also may be called in question by some but, if the definition of the Special Committee on the Lake Superior region be accepted, it would not be classed as Laurentian without some explanatory note.

Description of Formations.

Pleistocene.—Of this formation little can be said, as no detailed work has been done toward differentiating the various types of deposits, which include extensive areas of glacial drift and assorted sands, clays and gravel.

Keweenawan.—This series consists of extensive deposits of conglomerates, sandstones and marls. Some writers also include the Logan sills. In the area visited by the excursion no extensive deposits of sandstone are seen but the other features are well shown. In a cut on the Canadian Pacific railway one mile west of Loon an exceptionally fine outcrop of conglomerate, interbedded with small bands of sandstone is exposed. The boulders of the conglomerate are principally granite, though greywacke, iron formation and slate (Animikie), and amphibolite also occur. This conglomerate is cut by two narrow dykes of trap presumably connected with the Logan sills. The marls and impure sandstones are extensively developed near Silver lake, and in these are numerous veins sometimes containing sphalerite, galena and barite, but more frequently containing amethyst.

Possibly the most striking feature of this series is the trap formation known as the Logan sills. These intrude not only the older rocks but the Keweenawan as well, and are referred by some writers to a later age, while others look upon them as an integral part of the Keweenawan. These sills seldom exhibit their intrusive nature but appear as great lava sheets lying in a horizontal position over the Keweenawan and Animikie. The intrusive contact is best seen at Port Arthur, but near Loon the Animikie slates and iron formation are occasionally found overlying the diabase sills.

Upper Huronian (Animikie).—This series has been divided by Silver into the following divisions.

1. Black slate.
2. Upper iron formation.
3. Slate (somewhat calcareous.)
4. Thin bedded impure limestones.
5. Iron formation proper.
6. Quartz conglomerate.

The last of these is not more than six inches (15 cm.) in thickness, where it has been seen in this vicinity and consists of pebbles of vein quartz.

The other five members of the series are reduced by Mr. Smith to four divisions by omitting the thin bedded limestones which, according to an analysis by Mr. A. G. Burrows (**8**, p. 163), would appear to be ankerite in which the iron has been oxidized to ferric oxide. Mr. Smith looks upon these four divisions as representing one "continuous period of deposition during which the conditions varied between those of chemical and probably also organic sedimentation, producing the iron-bearing formations, and those of mechanical sedimentation with the production of the slates." (**6**).

The upper black slate has not been found around Loon lake, though in other places it is well developed. The upper iron formation is a thin bedded cherty iron carbonate resembling in texture the jaspilite of the Vermilion and Mesabi ranges in Minnesota. 'It varies in colour from dark grey to very light-coloured, although the most characteristic phase..............is a dark and light-banded rock.'(**6**)

The lower iron formation consists essentially of taconite, and all stages in the formation of iron ore may be observed in this formation. The slate between the upper and lower iron formations has not been described nor has any outcrop been located either on a published map or in printed descriptions.

Granite.—North of Loon lake is a series of hills of granite intrusive into the rocks which have been assigned to the Lower Huronian and the Keewatin. These hills are dome shaped and have been denuded by glaciation. That the original form of the intrusive mass was not materially different from the present form is shown by the presence of contact breccia over the surface of the hills. These masses are similar to if not identical in composition

with the granites that throughout this region have been referred to the Laurentian.

Lower Huronian and Keewatin.—Considerable difference of opinion is shown by those who have made a careful study of the formations in this region as to the dividing line between these two series. The writer has visited only one of the outcrops, which lies about a half mile south from Loon station and in his opinion it would be referred to the Keewatin if seen in a region where the bulk of the rock belonged to that age. The difficulty of making a distinction between the rocks of the two formations in this region is increased by the highly altered condition of the rocks, few of which show much trace of their original character. The two series consist of quartz porphyry exhibiting flow structure; greywacke, which has been altered to a considerable extent to schist; greenstone and a conglomerate, which, from the one illustration given (**8**) and the description of the constituents, may be compared with the Keewatin agglomerates of the friction breccia type.

ITINERARY.

In a southeasterly direction from the station at Loon is an outcrop of highly altered Keewatin or Lower Huronian which is exposed near a fork in the road. At Wylie's camp the same rock is well exposed. This rock shows considerable contortion and some minor faulting and is very similar to the more highly altered phases of the Keewatin. Along a trail to Silver lake from this exposure Animikie iron formation is well exposed at several places. The alteration of taconite to iron ore is well exemplified in an exposure on the south side of the trail and in the old shaft near Flaherty's camp. Good hematite (kidney iron) and taconite are well exposed at the tunnel on Flaherty's claim. Near this tunnel a fault is said to separate the Animikie from the Keweenawan. Some time will be devoted to the contact of Animikie and Keweenawan and to the character of the more marl-like material of the Keweenawan.

Returning southward along the trail the contact of the Animikie slates with the Logan sills may be noted. Continuing along the trail the Animikie may occasionally be found lying on the top of this sill. A view of Lake Decep-

tion well illustrates the type of lake scenery to be found in the Keweenanwan and Animikie rocks. Occasionally taconite, along with the Animikie slate, is found overlying the sill. A magnificent view of Thunder bay and Thunder cape can be seen from one of the more open spots a little farther along. In descending from this last point to the valley the contact of the sill with the underlying Animikie slates is passed. To the north is another exposure of taconite upon which some prospecting has been done. One mile west of the railway station, in a railway cut, is a remarkable conglomerate intersected by two small dykes apparently connected with the Logan sills.

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ANNOTATED GUIDE—(Continued).

Miles and Kilometres from Sudbury.

One mile (1·6 km.) west of Loon a remarkable conglomerate is exposed in a railway cut. From this point to Port Arthur the rock is of diversified character, including Laurentian, Keewatin, Animikie and Keweenawan, with no very striking exposures of any of them.

554 m. 891·5 km. **Port Arthur.**—Altitude 608 ft. (189·3 m.).

THE PRE-CAMBRIAN GEOLOGY OF PORT ARTHUR DISTRICT.

History of Exploration.

Port Arthur district has been widely known for many years because of its silver mines, which were at one time large producers. Of these, Silver Islet mine was the most noted, not only for the amount of silver obtained from it, but also for the Frue vanner which was invented by men connected with the mine and first used in the concentration of Silver Islet ore.

The first important description of this district was prepared by Sir. W. E. Logan (**1**). This was followed by a more extended description and a geological map by the same author at a later date. (**2**).

The explorations of Dr. R. Bell along the north shore of Lake Superior in 1869 (**3**) added materially to our knowledge of the rocks of this region, but unfortunately the map accompanying the report shows no geology so that it is difficult to estimate the scope of his work.

The first important work dealing in detail with the silver deposits was done by E. D. Ingall (**4**), who shows in a sketch map the geological boundaries as then known and the location of the mines. He also prepared a geological and topographical map of Silver Mountain mining district which gives the essential features of the geology of this region. A resumé of this report is given by Dr. W. G. Miller (**5**) to show the similarity of the silver deposits of Cobalt with those of Port Arthur district.

The latest work in this region was done by Dr. N. L. Bowen (**6**), whose report supplements that of Mr. Ingall by including the later mine development.

Geology of the District.

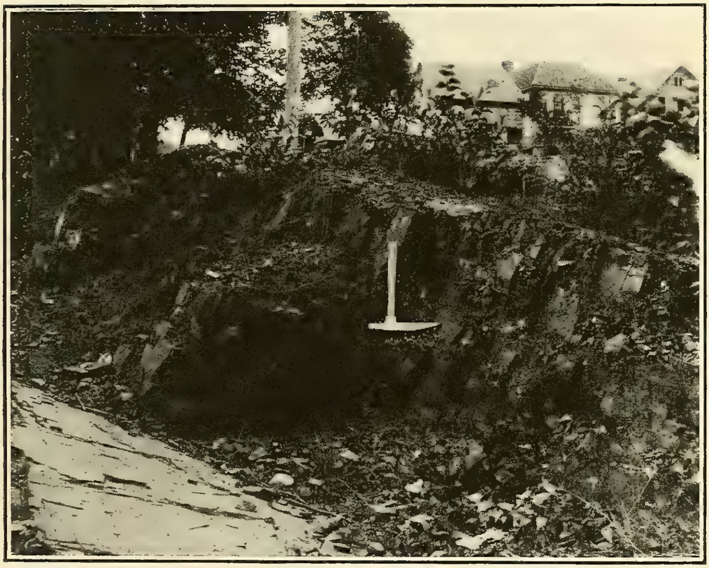
The geology of Port Arthur district is simpler than it is near Loon lake, because of the absence of the Keewatin and Lower Huronian . Only the Pleistocene, Keweenawan and Upper Huronian or Animikie occur in the immediate vicinity of Port Arthur. Laurentian and Lower Huronian rocks are to be found within four miles (6·4 km.) to the north of the city but are not exposed within the area visited by the excursion.

Pleistocene.—The Pleistocene has not been carefully studied, but consists not only of till, but also of assorted sands and gravels which frequently show marked cross-bedding. This latter feature is to be seen at many of the gravel pits along the railways where excavation has been recently done.

Diabase sill intrusive into slate; Current River Park, Port Arthur.

Keweenawan.—The Keweenawan in this region consists largely, if not entirely, of great masses of diabase which were intruded into the Animikie slates and iron formation in the form of extensive sills, known as the Logan sills. These sills have a marked effect upon the topography of the region, giving rise to flat topped hills, the upper parts of which are very precipitous, though the lower parts have gentle slopes due in part to the formation of talus. It was formerly supposed that these sills were surface flows as they were found capping the hills, but Dr. A. C. Lawson (7) showed that they were intrusions.

This rock is well shown in Current River park where a large area of rock was stripped of its covering of recent deposits by a flood caused by the bursting of a dam. Most of the surface rock so exposed is compact diabase, but numerous patches of black Animikie slate, ranging in thickness from a few inches to several feet, are scattered about over the surface. This slate is considerably baked by contact netamorphism, and the sill itself is finer grained near the contact than elsewhere, though at no part does it become very coarse grained. In some places through segre-

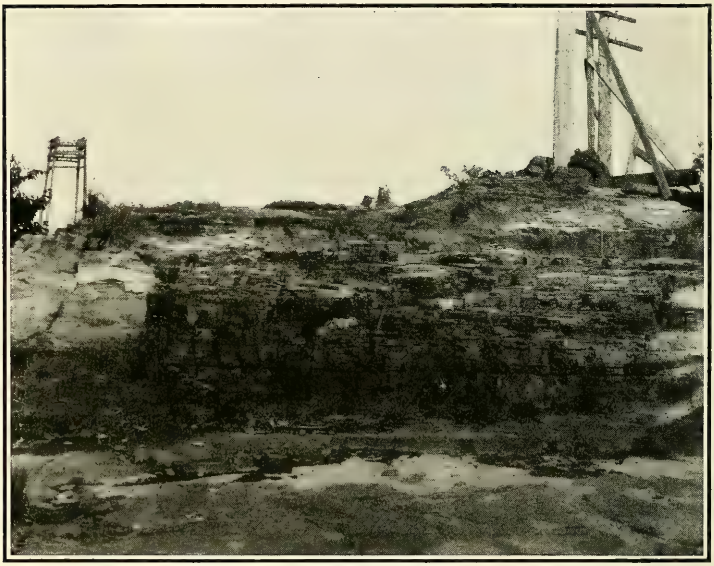


Black Animikie slate; Prospect Street, Port Arthur.

gation of the phenocrysts of labradorite the rock grades from a typical diabase into masses from two to ten feet (.6 to 3 m.) in diameter having the composition of anorthosite.

Animikie.—The Animikie or Upper Huronian is essentially a sedimentary series and is important as a silver and iron-bearing formation. The complete section is not well exposed at Port Arthur, but two of the members

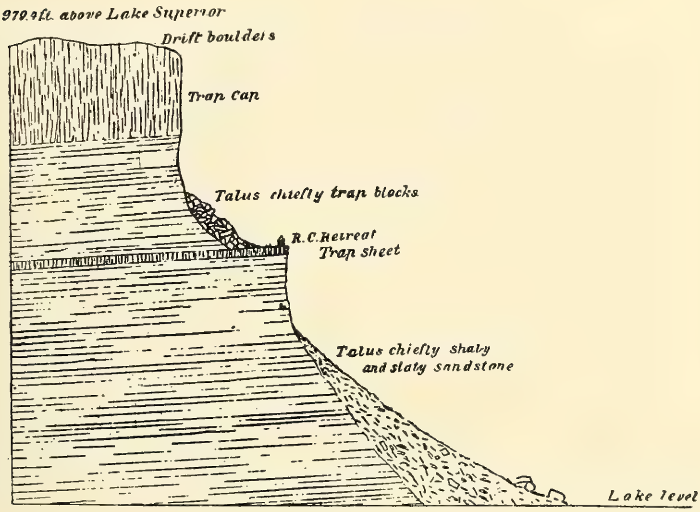
are well developed. The complete series is best observed near Kakabeka falls on Kaministiquia river. (**6**) It consists of (1) iron formation, including taconite, jasper, chert etc., (2) black slate, (3) grey quartzite with grey slate and (4) grey argillite. This agrees substantially with the sequence given by W. N. Smith (**8**) though the nomenclature is slightly different. It however, omits the basal conglomerate of L. P. Silver (**9**) as well as his thin bedded, impure limestone, which apparently are to be grouped with the iron formation.



Slates exposed in Stewart and Hewitson's quarry, Port Arthur.

This series is important economically, containing silver veins and extensive deposits of iron ore. Heretofore the iron deposits have not been so important in the Animikie of Ontario as in the same formation in Minnesota and but little mining has been done. Prospecting has however revealed several deposits of good ore of greater or less extent. In Port Arthur district, interest in this series has centered chiefly upon the black slates in which nearly all

the silver discoveries have been made. The silver is found in fissures in this rock near the intrusions of Keweenawan diabase, and in some cases the veins have crossed the diabase as well as the slate. The dark colour of the slate is largely due to the presence of carbonaceous matter which is thought to have been an important factor in the precipitation of the silver, for the silver is said to be always accompanied by carbonaceous matter.



Section through Mt. McKay near Fort William, Ont. The trap here bears a similar relationship to the slaty series to that which it has in the Cobalt area. Some silver veins in the Port Arthur area cut both the trap and the slate. (After Dr. A. C. Lawson.)

The most noted mines of this vicinity are the Silver Islet, Silver Mountain, Beaver, Badger, and Porcupine. None of these have been worked to any great extent since the fall in the price of silver in 1892.

Itinerary.

At Current River park the Keweenawan traps and overlying slate are first noted. Usually the slate is not more

than a foot in thickness, but near the Canadian Pacific Railway track there is an exposure several feet in thickness.

Returning to the city an excellent view of Mt. McKay may be seen from the Lookout near the collegiate building. By reference to the accompanying section the effect of the diabase sills upon the form of the mountain may be observed. The Lookout itself is interesting in that it is built of materials representing most of the Pre-Cambrian rocks of the region. An outcrop of black Animikie slates occurs near the corner of Prospect Street and the car line, and at the corner of Hebert and College Streets is a good exposure of taconite. Slates and Keweenawan trap are well exposed in the Stewart and Hewitson's quarries at the end of Hill street, and in the former, slaty cleavage is well developed. Silver was found in a vein in this quarry. The large quarry near the crushing plant shows several well defined veins, filled with calcite, fluorite and barite, which penetrate both slates and diabase.

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PORT ARTHUR TO WINNIPEG VIA CANADIAN NORTHERN RAILWAY.

BY

W. L. UGLOW.

INTRODUCTION.

The excursion over the Canadian Northern railway from Port Arthur to Winnipeg affords an opportunity of seeing an unusually complete Pre-Cambrian section. Within this distance of 230 miles (370 km.) every Pre-Cambrian series that had been differentiated in the Lake Superior region is exposed to a greater or less degree. In addition, the base of the section is formed by the Coutchiching series, one that is rare in other localities, and which is claimed by those who have studied it specially, to be even older than the Keewatin. The area also contains, in exposures of fossiliferous Lower Huronian limestone, the oldest known records of life.

A few broad topographic features should be mentioned at the outset. Two chief types of topography are well represented: the rocky lake country, and the alluvial plain. Generally speaking, the former occupies the eastern part of the region traversed, although the first 25 miles (40 km.) of the trip are across the post-glacial flood-plain of Kaministiquia river. West of Rainy lake, rock exposures and hills are rarely seen, and the level country passed through is in part the alluvial plain of Rainy river, and in part the bed of glacial Lake Agassiz, (**12**) which continues to Winnipeg.

The most recent classification of Canadian Lake Superior geology is that by Dr. Andrew C. Lawson in his new report (**6**) on the Rainy Lake region. For purposes of reference his table of formations is reproduced below, in full. What are believed to be the equivalents of the various series in the nomenclature of the International Committee and of the United States Geological Survey are included in parentheses.

Algonkian (No equivalent).	Keweenawan (Keweenawan). *Unconformity.* Animikie (Upper Huronian).

Eparchacan Interval—Unconformity between the Middle and Upper Huronian.

Archaean (No equivalent)	Algoman (granites intrusive into the Lower and Middle Huronian). *Irruptive contact.* Seine series (Middle Huronian). *Unconformity.* Steeprock series (Lower Huronian). *Unconformity.* Laurentian (Laurentian). *Irruptive contact.* Ontario Keewatin (Keewatin). (Keewatin) Coutchiching (No equivalent?).

A short quotation (**6**) will explain Dr. Lawson's method of subdividing the series below the Cambrian: "Upon the vast peneplain resulting from degradation during the Eparchaean Interval were deposited the Animikie sediments. The Animikie is thus separated from the Huronian by an enormous interval of geological time. On the far side of that interval the earth's crust was affected by plutonic activities, involving the Coutchiching, Keewatin and Huronian similarly, which have not recurred in the region so far as is known on the near side of that interval. In other words, the Huronian is allied in its geological history with the Coutchiching and Keewatin, and is part of the Archaean, while the Animikie (Algonkian) is allied with the Palaeozoic."

In order to complete the geological sequence exposed along the Canadian Northern railway, there should be mentioned an outcrop of Richmond fossiliferous limestone (Ordovician), found by Dr. Lawson, about six miles (9·6 km.) west of Fort Frances, and believed by him to represent an outlier of the Palæozoic rocks more abundantly exposed in the valley of the Red river in Manitoba.

ANNOTATED GUIDE.

(Port Arthur to Iron Spur.)

Miles and Kilometres.

0·0 m. 0·0 km. **Port Arthur**—Altitude 607 ft. (185 m.).

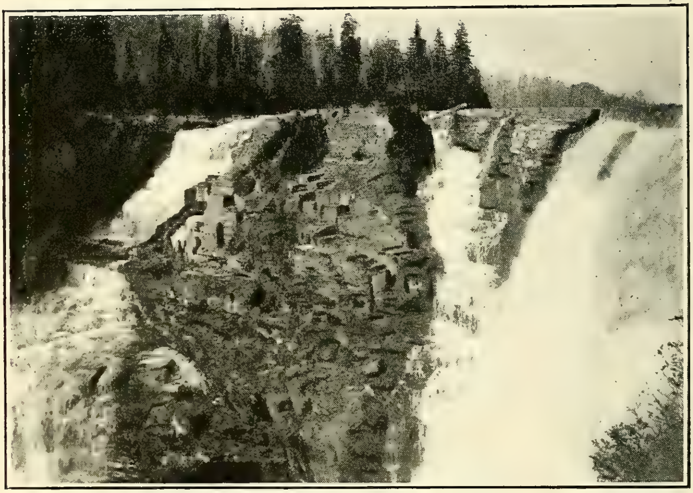
3·0 m. 4·8 km. **Fort William**—Altitude 612 ft. (186 m.). These two cities, commonly known as the "Twin Cities," are located at the head of the Great Lakes system of navigation. The rocks underlying Port Arthur and Fort William consist of apparently flat-lying Animikie sediments (slates, indurated shales, cherty dolomites, etc.) and Keewenawan diabase sills. The characteristic topography produced by the erosion of this group of rocks can be seen in the islands and shores of Thunder bay. The flat-topped, steep-sided outlines of these hills are produced by cappings of diabase which have protected from erosion the underlying sediments. In some sections more than one sill may be observed.

Leaving Port Arthur, the train takes a southwesterly course across the post-glacial flood-plain of the Kaministiquia river to the towns of Fort William and Westfort. A short distance to the south of Westfort, McKay Mountain rises to a height of 1,600 feet (488 m.) above the sea, and exhibits pronounced mesa-like outlines. The horizontal attitude of the sills and Animikie sediments, as well as the vertical columnar jointing of the former, may be readily observed from the train. After passing Westfort, the soft, rounded outlines and roche montonée topography characteristic of the southern part of the Archæan terrane, appear in the far distance to the north and northwest.

23·4 m. 37·7 km. **Kakabeka Falls**—Altitude 912 ft. (278 m.). Up to this point, and for some distance beyond, the railway traverses the flood-plain of the Kaministiquia, and the total absence of rocky hills near at hand is a striking feature . Near the station, however, the Kaministiquia drops a short distance over Archæan granite-gneiss, and

Miles and Kilometres.

for half a mile (0·8 km.) below flows down a low gradient to the great falls, which are over a cliff of horizontal Animikie indurated shales, 150 feet (45·7 m.) high. The Animikie-Archæan unconformity is not well exposed, although traces of a basal conglomerate are found plastered on horizontal surfaces of the granite gneiss. But the structural discordance between the comparatively undisturbed Animikie strata



Animikie indurated shales, Kakabeka falls.

and the highly sheared Keewatin greenstones, which outcrop a short distance away, is sufficient proof of uncomformable relations.

82·3 m. 132·5 km. **Kashaboiwe.** From this locality westward to the vicinity of Kashaboiwe a belt of Keewatin greenstone and felsite schists is followed. In association with this belt are lenses of iron formation which constitute what is known as the Mattawin iron range. The iron-formation is generally banded in character, and deposits of clean ore

Miles and Kilometres.

occur of both the magnetite and hematite types. The granite-Keewatin contact is crossed just west of Kashaboiwe, and the greyish-white granitic hills are a prominent topographic feature from this point to near Huronian.

97·1 m. 156·2 km. **Huronian.**—The next 25 miles (40 km.) to Kawene station afford an excellent opportunity to observe the intrusive relations between an Archæan granite-gneiss and a distinctly sedimentary series. Sufficient detailed work has not yet been done in this part of the region to definitely correlate these rocks, but, in all probability, they are the Algoman granite and the Seine sedimentary series, which will be examined in detail at Iron Spur. An excellently developed contact breccia continues with abundant exposures for the whole distance, and may be readily observed in a general way while en route.

121·6 m. 195·7 km. **Kawene.**—At Kawene the contact swings south of the track, and from here to mile post 126 excellent exposures of the Seine series occur on both sides. At this mile post, the contact is again crossed, and the Algoman granite continues to Iron Spur.

123·8 m. 206·4 km. **Iron Spur**—Altitude 1,400 ft. (427 m.) From this point a trip is taken three miles (4·8 km.) along a spur line to the site of the Atikokan iron mine to observe the irruptive contact between the Algoman granite and the Seine series, and to examine the high-sulphur iron ore-body.

GEOLOGY OF THE VICINITY OF IRON SPUR.

General Statement.

The general elevation of the country surrounding Iron Spur is between 1,300 and 1,500 feet (396 and 457 m.) above sea-level, or from 700 to 900 feet (214 to 275 m.) above Lake Superior. The outstanding features of the physiography are the low rounded hills that characterize the Pre-Cambrian in this part of Canada. The intervening areas consist occasionally of glacial drift, but more usually of alluvial material, forming what are commonly known as muskegs.

The geological series represented in the vicinity are, in descending sequence, according to the nomenclature of Dr. Lawson:

Archæan	Algoman
	Irruptive contact.
	Seine series
	Unconformity.
	Keewatin.

Keewatin.

Exposures of this formation are rather rare in the immediate neighbourhood, but occur a short distance north of Atikokan river as part of a N. E.–S. W. belt. The rock types represented are greenstone, gabbro, felsites (quartz-porphyries) and their schistose equivalents.

Seine Series.

This consists of a group of rocks, which typically consists of dark-coloured micaceous quartzites, quartz slates and greywacke slates, grading into sericitic schists. Their appearance, both on fresh and weathered surfaces is decidedly sedimentary. In other localities they are found to be unconformably above the Keewatin and Laurentian.

Algoman.

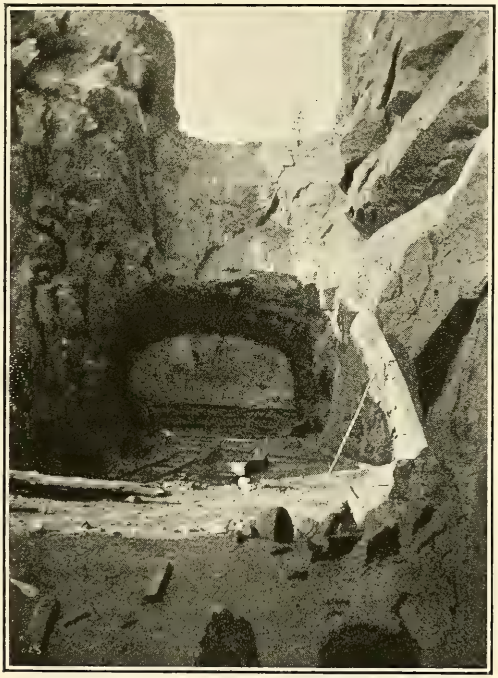
This is primarily a biotite granite of medium to coarse-grained texture. It varies between granite and syenite types, and usually contains phenocrysts of acid feldspar. Previous to the summer of 1911 it was mapped by Canadian geologists as part of the Laurentian. But now, in this locality, a small oval-shaped area is differentiated, owing to the fact that it intrudes a well-defined, water-deposited series. It is believed that a considerable part of the rocks mapped as Laurentian in this part of the province is really younger than the Seine series and therefore of Algoman age.

The area was mapped in 1897 by W. McInnes and the late W. H. C. Smith for the Geological Survey as part of the Seine River sheet. Since that time Dr. A. P. Coleman and others have visited the region in connection with studies of the Lake Superior iron ores. The most recent work in the area was done by Dr. Lawson during a visit

to this locality in the summer of 1911, and by the late Dr. J. D. Trueman in the early summer of 1912.

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

Ore-body at the Atikokan Iron Mine.—The iron ore deposit occurs in a rocky ridge running approximately east and west, just north of the track and about 2·75



Open cut, Atikokan iron mine, Iron Spur, Ontario.

miles (4·4 km.) from the beginning of the spur. The rocks in the vicinity of the mine are very imperfectly exposed. The ridge itself is isolated, being bounded by a muskeg on the south, and separated by a valley from a ridge of Keewatin greenstones to the north.

The ore is magnetite, rather freely supplied with sulphides, chiefly pyrite, but also including traces of chalcopyrite. It occurs as a series of overlapping lenses, separated from one another by walls of greenstone, and bounded on the north side by a wall of highly sheared acidic rocks. Associated with the ore and interlaminated with it, are beds of greyish-white chert and dark green slate. In places along the strike, especially near the east end, narrow beds of ore, chert and slate may be seen interlaminated with each other. The ore-bodies and associated rocks have a common strike and dip, the later varying from vertical to 60° north.

The following account of the origin of the ore-body is given by Dr. Lawson in a forth coming report of the Geolical Survey of Canada, and on account of its dissimilarity to other interpretations is worthy of quotation almost in toto:

"Iron ores occur either at the contact or close to it where there is no conglomerate. The ore and the conglomerate thus appear to be in a certain sense complementary features of the base of the Seine series. It is interesting to note in this connection that the pre-Seine surface of the Keewatin greenstones, where it emerges from beneath the Seine series, is commonly heavily charged with carbonates (including siderite or ankerite) and limonite. This condition in some sections obtains for several hundred feet away from the contact, and with little question it represents the effect of the weathering of the Keewatin surface in pre-Seine or early Seine time. It suggests a supply for the iron ore that is found in workable bodies and in less important prospects along the line. The concentration may have been effected in bogs in early Seine time, a possibility which harmonizes with the absence of conglomerate at such points along the contact; or it may have been concentrated by underground circulation after the burial of the weathered and iron-rich surface by the Seine sediments."

Particular interest attaches to this particular occurrence, because of the successful attempt of the company to use an ore which is not only hard but also markedly rich in sulphides.

The mine has a good surface equipment, and the company owns an up-to-date blast-furnace at Port Arthur which was designed and erected primarily for the treatment of

the high-sulphur Atikokan ores. Before being smelted these ores are specially treated to eliminate the sulphur, so far, with remarkable results.

Irruptive Contact of the Algoman Granite with the Seine Sedimentary Series.—The phenomena to be observed in this connection extend from a point on the railway spur one eighth of a mile (0·2 km.) from the main line along the spur to the main line, and then for an eighth of a mile (0·2 km.) westward along the main line. On returning from the iron mine, the following points in connection with the intrusion can be noted in the order given.

1. Dykes and stringers of granite cut the dark-coloured, anamorphosed phase of the Seine series, and frequently traverse it across the bedding.

2. Angular to rounded fragments of the altered Seine rocks are abundant within the granite mass.

3. Assimilation of these inclusions by the intrusive is shown by its abundant content of hornblende and general adoption of a basic phase near the intruded series.

4. A short distance from the contact, the Seine rocks resemble a dark-coloured gneiss, rich in quartz and biotite with stringers of lighter-coloured, more or less feldspathc material.

5. The passage from this anamorphosed variety through a less altered one to the normal phase may be well followed by observing the exposures in two railway cuts, about an eighth of a mile (0·2 km.) along the main line and just west of the section house. The character of the anamorphosed Seine series should be especially noted in order that it may be compared with that of the Coutchiching series in the Rainy Lake area.

ANNOTATED GUIDE (Iron Spur to Atikokan).

After leaving Iron Spur occasional exposures of the Seine series, separated by stretches of muskeg occur on both sides of the line. The valley of Atikokan river follows rather closely from the crossing just west of Iron Spur.

Miles and Kilometres.

131·6 m. 211·9 km. **Hematite**—Altitude 1,360 ft. (415 m.) From this point westward to Atikokan, the railway marks approximately the contact of the Seine with the Keewatin group. The latter stands out in much weathered exposures of greenish-coloured schists in the hills just to the north of Atikokan river. To the south and usually in the rock-cuts along the railway may be seen the quartzites and quartz slates of the Seine series. The iron formation of the Atikokan range which outcrops at intervals on both sides of the track is probably an extension of the ore-bodies northeast of Iron Spur. Half-way between mile posts 139 and 140, there seems to be an actual contact between the Seine series and the Keewatin but no trace of a basal conglomerate could be found. With the exception of a short space just east of mile post 141, occupied by Keewatin greenstones, exposures of the Seine series continue more or less intermittently to Atikokan.

142·4 m. 229·5 km. **Atikokan**—Altitude 277 ft. (389 m.). From this point a side excursion occupying half a day is taken to Steeprock lake to examine the fossiliferous limestone and the structural features of the Steeprock sedimentary series of the Archæan.

GEOLOGY OF THE VICINITY OF STEEPROCK LAKE.

General Description.

The physiographic features of this region are typical of those in the southern part of the Pre-Cambrian terrane. The rocky lake country, which is here well exemplified, presents the character of a peneplain. Regarded on a large scale, it is remarkably flat and devoid of prominent elevations, but, when considered in detail, the surface is extremely uneven and hummocky.

The general geology of the region was partially worked out by Dr. Lawson for the Geological Survey in the summer

of 1911, and on his report (**7**), recently published as a memoir of the Survey, is based the following description.

The only rocks known in the area to be visited are those of the Keewatin, Laurentian, Steeprock, and Seine series. The position of the Steeprock series, well down in the Pre-Cambrian, is of interest for the reason that the limestone of which it is chiefly composed, is fossiliferous.

Keewatin.—This is the oldest group in the region and consists chiefly of felsites (quartz porphyries), gabbros, diabases, greenstones, and their schistose equivalents, as well as occasional exposures of tuffs and agglomerate schists. The strike of the schistosity varies from place to place, but seems in a general way to accord with the contour of the lake shore.

Laurentian.—This is primarily a medium-grained hornblende granite gneiss, showing only a slight foliation in the Steeprock area. Near its contacts with the Keewatin, it not only holds as inclusions large fragments of the older series, but itself becomes quite basic, and grades into a type closely resembling typical Keewatin hornblende schist. In places, however, very sharp contacts of the two series in their normal phases are exposed. On account of its somewhat bleached appearance, and of its association with much sheared varieties in neighbouring localities, the series is correlated with the Laurentian.

Steeprock Series.—The rocks thus designated include the following formations in descending order:

4. Green schists, evidently of detrital origin, traversed by dykes and flows of diabase and diorite.

3. Volcanic ash, highly pyritiferous, schistose rock, often containing fragments of limestone and black cherty material.

2. Limestone, dolomitic to sideritic, and usually weathering brown. The exposures at the sharp bends in the shore-line of the lake are a brecciated variety, consisting of angular fragments of limestone, black chert, and typical Keewatin rocks.

1. Basal conglomerate, usually fine-grained, and frequently of the nature of a quartzite or arkose.

The rocks of the series are almost in a vertical attitude, the prevailing dips being 70° to 90° S.W. The series is tentatively correlated with the Lower Huronian.

Seine Series.—Quartzites and quartzose slates of the normal type, striking almost east and west, occur some

distance south of the lake, and along the Canadan Northern Railway line in the vicinity of Atikokan.

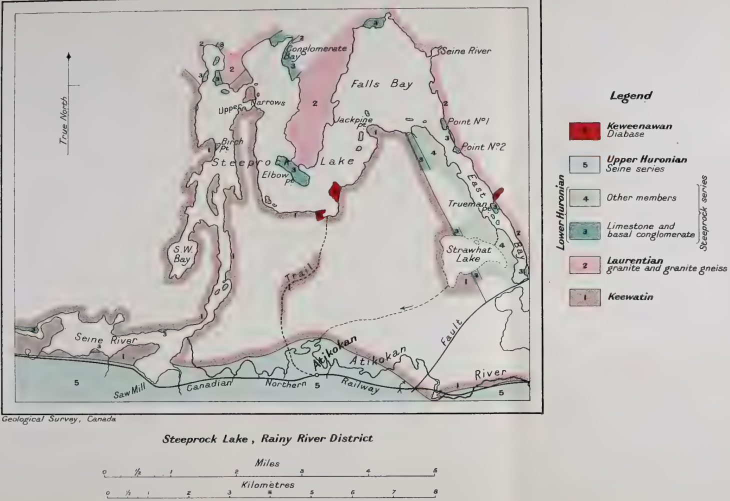
Structure of the Area.—A good partial cross-section of the Steeprock series is exposed along a line from the west side of Strawhat lake to the east side of East bay. In this section, a twofold repetition of the same set of beds in reverse order is evident. The general strike is N.W.-S.E. On the east, the conglomerate is in visible contact with the Laurentian, while on the west it rests on the Keewatin basement. The structure which has been worked out for the area by Dr. Lawson is that of a simple, closely folded syncline, whose axis is parallel to East bay, and whose trough covers the contact of the Laurentian and Keewatin.

In contrast with the folded condition of the Steeprock series is the uniform monoclinal attitude of the Seine quartzites and quartz slates. This stratigraphical and structural relationship indicates that the folding, which involved the Steeprock series as a sharp trough sunk down into the older Archæan, had taken place anterior to the deposition of the Seine series. It is therefore inferred tentatively that the Steeprock series is older than the Seine series.

The distribution of the Steeprock series and of its limestone and basal conglomerate members, as far as they have yet been differentiated from the Keewatin, is shown on the accompanying map. The exposures in the southwest corner on Seine river are a brownish calcareous schist, not unlike that on the south shore of Falls bay. They are, however, very closely associated with Keewatin felsites, and may be either Keewatin in age or infolds of the Steeprock limestone.

The areal geology, indicated on the map, is only approximate, as detailed surveys have not yet been made.

Progress of Exploration. The geology of the area, on account of the features of especial interest which it presents, has received considerable attention from the Geological Survey of Canada and other sources. In 1891, H. L. Smyth (**10**) published an interesting set of results obtained from an examination of the area. W. McInnes and the late W. H. C. Smith (**4**) of the Survey mapped the region as part of the Seine River sheet in 1897. Dr. A. P. Coleman visited the area and published an interesting account of the geology in 1898 (**2**). In 1911, Dr. Lawson spent some time



Geological Survey, Canada

Steeprock Lake, Rainy River District

in the neighbourhood, and in his report are embodied the results of the most recent work.

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

Leaving the train at the station, a path is followed for 2·6 miles (4·2 km.) to Steeprock lake. At three-fifths of a mile (1 km.) from the station the first rock exposures are seen. They consist chiefly of Keewatin felsites, quartz-porphyries, and their derived schists, with which are associated, however, small lenses of a quartz conglomerate which may be infolds of the base of the Seine series. Exposures continue for about a mile (1·6 km.) farther, and are mostly of Keewatin acidic and basic types, although occasional small outcrops have a remarkably sedimentary aspect.

After embarking in the boats a straight course is taken to Jackpine point. On the left-hand shore are hills of Laurentian granite gneiss, while on the right Keewatin felsites and felsite schists, cut by dykes of post-Keewatin diabase, are exposed to view. At the north end of Falls bay a high brown bluff, consisting chiefly of the brecciated phase of the Steeprock limestone, stands out bcldly. Just as Jackpine point is reached a glimpse of Steep falls to the northeast may be obtained.

Cross-section of the Keewatin and Steeprock Series on the South Shore of Falls Bay.—In walking over this section from west to east, the Keewatin rocks are first noticed on Jackpine point where a schistose pyroclastic is splendidly exposed. The fragments are of the same material as the matrix, and although elongated in the general direction of the cleavage are not schistose like it. East of this are exposures of typical hornblende, chlorite, and felsite schists.

The basal conglomerate of the Steeprock series is well exposed next on a glaciated surface which extends for 150 feet (46 m.) across the strike (N 40° W). It should be noted that the pebbles are chiefly quartz and granite, with a few smaller ones of Keewatin diabase and greenstone. To the east of this is a brown calcareous schist with lenses, at times a foot (0·32 m.) thick, of ferruginous limestone. This is all of the western limb of the Steeprock limestone that is exposed on the south shore, but it is believed that

more of the formation and also a bed of volcanic ash occupy the depression in which the creek flows.

East of the creek are green schists of detrital origin traversed by sheet-like masses of diabase and diorite, which may be dykes or flows and which are younger than the Steeprock series. With these intrusions there seems to be associated diabase dykes which cut the granite and greenstone in such a way that they apparently represent the orifices through which the larger masses found their way to their present position.

Fossiliferous Limestone at Point No. 1.—By crossing in an easterly direction to a steep brown bluff, the first exposure of the limestone in the eastern limb of the syncline may be examined. The contact with the older rocks is not exposed here, but lies under the drift in the depression just to the east. An example, on a small scale, of the deformation which the formation once suffered, may be seen at the western corner of the point. The original bedding and joint-planes of the limestone are rendered visible by the abundant development of lime-silicate minerals along them, which have weathered into relief. A small exposure of a calcareous green schist probably developed from the limestone may be seen also at this point. The attitude of the beds should be observed.

The fossils are located chiefly at the southern corner of the bluff, and are quite abundant, especially near the waters edge. *Atikokana lawsoni* (**15**) seems to be the main species represented at this point. It is one of a group of organisims related to the sponges. Both silicated and calcareous varieties occur.

From Point 1 a southeasterly course is taken to Point No. 2, about half a mile (0·8 km.) distant. Along the route bold Laurentian hills easily distinguishable by their pale pink weathering, may be seen to the east. Dark-coloured patches occur scattered here and there through the gneiss. In some cases there are dykes similar to those associated with the crystalline traps of the Steeprock series, while in other cases there are detached masses of the intruded Keewatin engulfed by the granite when still in a viscous condition. The Laurentian-Keewatin contact zone is approximately in the trough occupied by the lake. A narrow fringe of limestone which may be distinguished by its brown colour, extends almost continuously along the east shore between the two points.

On the west side of the bay, the geology is quite different. The high ridge which roughly parallels the bay consists chiefly of the crystalline traps (diabase and diorite) and associated clastic green schists of the Steeprock series. Along the waters edge, directly west from Point No. 2, is a small exposure of the volcanic ash of the same series.

Fossilferous Limestone and Unconformable Contact of the Steeprock Series with Laurentian at Point No. 2.—At this locality, the attitude of the limestone beds is well marked, and may be best seen in the bay at the south end of the bluff. From this bay a trail leads a short distance up the hill over granite, and then swings northwestward across the unconformity. A continuous section at right angles to the contact is exposed. The granite may be followed westward from a comparatively unaltered phase through 45 feet (13·7 m.) of a schistose, gritty, bleached variety to the Steeprock series basal conglomerate. The transition is not a sharp one. The conglomerate, which contains small pebbles, chiefly of quartz and fine-grained granite, is from 5 to 8 inches (12·7 to 20·3 cm.) thick and is followed in the direction of the limestone by 50 feet (15·2 m.) of thinly bedded impure, quartzitic and slaty rocks. The limestone is in sharp contact with these. The nature of the unconformity should be carefully noted in order that it may be compared with that between the Laurentian and Seine series to be seen on the Mine Centre trip.

Fossils are best seen on the face of the bluff near the waters edge.

Fossiliferous Limestone at Trueman Point.—From Point No. 2 the course is a direct southeasterly one up the bay, with exposures of the basement complex on the east and of the Steeprock series on the west.

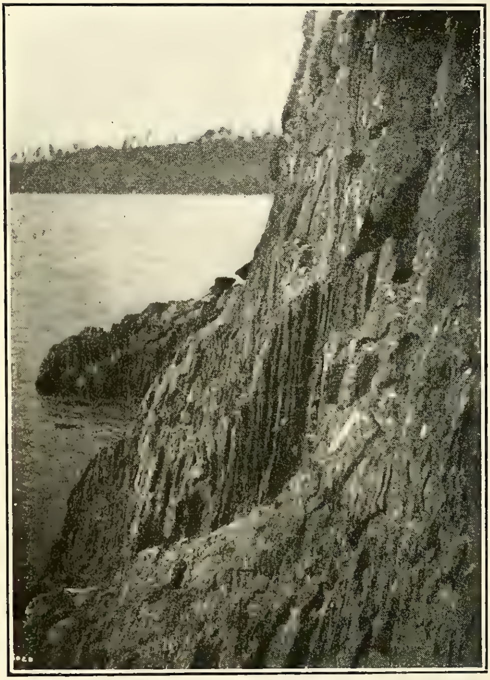
A ledge on the eastern side of Trueman point, near the narrow rock joining it with the main shore is the locus of Dr. Lawson's original discovery of fossils. Two varieties are to be found. They are quite abundant near the waters edge, especially along the face of the bluff.

The contact of the limestone with the older rocks is not exposed, but the fragmental formation between the limestone and the granite gneiss may be seen on the side of the hill just east of the southern landing.

In places the limestone is quite sideritic, and appears as a thinly-banded, brown and grey rock, resembling a

lean phase of the iron formation. This variety is exposed near the centre of the west face of the bluff, where there is a slide of talus material.

The attitude of the beds is well shown near the waters edge, where there is an abundant development of the lime silicates, which have weathered into marked relief.



Fossiliferous Steeprock limestone, Trueman point, Steeprock lake, Ontario.

A dyke of quite unaltered diabase cuts the Laurentian about 500 feet (152 m.) north of the northern landing, and probably represents a vent through which some part of the sills or flows in the Steeprock series reached their present position. Numerous basic, dyke-like masses cut the granite in this neighbourhood.

Brecciated Limestone at Elbow Point.—From Trueman point a direct return trip is made to the northwest end of Elbow point, where a breccia made up of angular fragments of limestone, black chert, and Keewatin felsite and greenstone, cemented together by crystalline limestone is well exposed. Interbedded with this are layers of a more or less pure limestone. As pointed out above, these brecciated phases are chiefly exposed at the sharp bends in the shore-line.

After examining this locality, the return journey is made to Atikokan.

ANNOTATED GUIDE.

(Atikokan to Mine Centre).

Miles and kilometres.

Beyond Atikokan the railway proceeds in a general way down the valleys of the Atikokan and Seine rivers for 35 miles (56·4 km.). The Seine series-Keewatin unconformity, with the younger series on the south side, follows with minor irregularities the bed of Seine river almost as far west as Mayflower. Occasional exposures of the Seine series are seen along the railway, except in two small stretches from mile posts 147 to 149, and from 159 to 161, where the contact swings south of the railway, and parts of the Keewatin belt are crossed.

160·0 m. 257·8 km. **Banning**—Altitude 1,256 ft. (383 m.). In this vicinity, diamond-drilling for iron ores has been carried on recently, but the results have not been highly satisfactory. The outcrops, which are of a hard iron formation in association with Keewatin greenstones, lie close to the railway and constitute probably part of the western extension of the Atikokan iron range.

After passing mile post 161, splendid exposures of the Seine schists and slates may be seen in the cuts on both sides of the railway as far west as Mayflower.

164·7 m. 264·9 km. At this point a stop of about fifteen minutes is made to examine a case of post-glacial faulting (8) in the Seine series. The exposure is just

Miles and Kilometres.

a few feet south of the track, and the chief points to be noted are:—

1. The nature of the rocks—phyllitic slates.

2. The strike and dip of the bedding or cleavage planes.

3. The reverse or overthrust character of all the faults.

4. The constancy of direction of the glacial striae, and their extension on both the upthrow and downthrow sides to the very edge of the fault plane.

5. The sharpness of the fault scarps.

6. The coincidence of the fault-planes with the cleavage of the slates.

7. The absence of fault breccia or slickensides.

8. The absence of any horizontal component in the differential movement.

9. The number of fault scarps (24 in 66 feet (20 m.) across the strike), and their average height.

10. The presence of a transverse fault.

11. The presence of one stepped scarp.

For reasons explained in his paper (**8**) Dr Lawson ascribes the faulting not to orogenic forces, but rather to the play of compressional and relaxational forces resulting from change of temperature or load. He cites other examples from geological literature of such faulting, and concludes that it is peculiar to slaty rocks.

165·0 m. 265 km. **Mayflower.**—From a short distance west of Mayflower to milepost 169, the Seine-Keewatin unconformity is again south of the railway, and Keewatin rocks are exposed on both sides. For the succeeding eight miles (12·8 km.) the railway runs in a northwesterly direction and affords a partial section of the Seine series, through the quartzites and slates to the basal conglomerate, which is excellently exposed just west of Mathien. (176 m., 283 km.)

The remainder of the trip as far as Mine Centre is through a drift-covered area underlain by the Keewatin which outcrops only at intervals.

Miles and Kilometres.

190·5 m. 306·5 km. **Mine Centre.**—Altitude 1,190 ft. (363 m.) From this point a trip is taken to the site of the Golden Star mine on Bad Vermilion lake to examine the following points: an occurrence of limestone in the Keewatin series; the contacts of the Seine series with the Keewatin, of the Seine series with the Laurentian, of the Laurentian with the Keewatin, and of the anorthosite gabbro with the Keewatin; and the lithological characteristics of the rocks of the various series.

GEOLOGY OF THE VICINITY OF MINE CENTRE.

GENERAL DESCRIPTION.

The area to be visited has the typical physiography of the southern part of the Pre-Cambrain terrane, and is not essentially different from that of the Steeprock lake area. Bad Vermilion lake is six miles (9·6 km.) long in a direction a few degrees south of west, and follows in a general way the strike of the Keewatin schists. It contains comparatively clear water, and has depths of 400 feet (122 m.) and over in places. The bold, glaciated rocks on the southern shores stand out prominently.

The general geology of the area is identical with that of a great part of the region just passed through. The particular interest attached to this locality is due to the remarkably well exposed contacts which lie within 500 feet (152 m.) of the old mine. The geological succession, in descending order, is:—

Archaean........	Seine series.
	Unconformity.
	Laurentian.
	Irruptive contact.
	Anorthosite (Keewatin?).
	Irruptive contact.
	Keewatin.

Keewatin.—Typical rocks of this series are well exposed in the area, and consist of greenstone, green schist, diabase,

agglomerate schist, felsite, felsite schist and a limestone and chert formation.

Anorthosite.—This is a highly feldspathic saussuritized gabbro or anorthosite which is areally disposed like a collar about a central heart-shaped boss of granite. It is clearly intrusive into the Keewatin, presumably in the form of laccolithic lens which tapers westward. The intrusion took place probably before the severe deformation of the Keewatin, for the gabbro is itself intensely sheared locally. The rock contains in places crystals of anorthite 10 inches (25 cm.) in diameter.

Laurentian.—This consists of a medium to coarse-grained, light-coloured, biotite granite, locally poor in biotite, and thereby grading into alaskite. It is intrusive into the anorthosite, as well as into the Keewatin, and it is believed, from the areal relations of the rocks, that it attained its present position by arching up the lenticular anorthosite sheet.

Seine Series.—Within the area under discussion the Seine series is represented chiefly by a great thickness of basal conglomerate which grades upward into typical quartzites and slaty schists. The conglomerate contains a large amount of debris derived from the waste of Keewatin rocks, but the pebbles and boulders, which are usually well water-worn, consist chiefly of different varieties of granite with a subordinate proportion of greenstone, quartz porphyry and dark coloured chert pebbles.

Particular Description of Points to be Visited.

The Keewatin Series seen en route to the Mine.—A trail about half a mile (0·8 km.) long leads from Mine Centre station southwest to the shore of Bad Vermilion lake. Two ridges of Keewatin rocks are crossed by this trail. One, just south of the village, consists of highly schistose felsites and quartz porphyries, while the other, which borders the north shore of the lake, is made up of quite basic rocks, which are greatly deformed, owing, no doubt, to their proximity to an area of intrusion.

The lake is crossed in boats to the road leading to the burnt remains of the Golden Star mine. Here Keewatin greenstones and felsites are exposed on all sides.

A trail, leading directly south across the hill, is followed for about 300 feet (91.4m) to where it joins the mine road.

On top of the hill may be seen excellent exposures of the Keewatin, consisting of calcareous schists with lenses of ferruginous limestone, and a band of schistose volcanic agglomerate. The road eventually leads to a well, which is the starting-point for the first side trip.

Limestone Bands in the Keewatin.—From the well, a path 500 feet (152 m) long, marked by yellow flags, leads to an exposure of Keewatin limestone. On the right hand side of this path, before coming to the limestone may be observed ridges of grey-green weathered felsite, much fractured as a result of igneous intrusion.

The limestone occurs in a series of bands from a few inches to a foot thick, which are interlaminated with discontinuous bands of chert and chert agglomerate. The total width of the formation is about 10 feet (3.2 m), and it can be traced along the strike for 275 feet (84 m). The strike is N 65° E, and the dip 50° to 60° N. W. The limestone is a highly granular, medium-grained variety, containing an abundance of minute crystals of brown mica scattered through its mass. An analysis shows that it contains only 0.35 per cent $MgCO_3$. Resting upon the limestone is a two foot (0.61 m) bed of brecciated chert, which grades upward into a porpyhritic dense felsitic lava. The proof of the contemporaneity of the limestone and the felsite is important in discussing the relation of the limestone to the Seine series.

Unconformable Contact of the Seine Series with Keewatin Felsite.—The mine road (marked by white flags) is next followed in a southeasterly direction for 200 yards (183 m), up a hill of felsite cut by basic igneous dykes. The ruins of the mine, which was destroyed by the Rainy Lake fire of three years ago, may be seen on the right. A path marked by blue flags, leading to the left is then taken. It affords an opportunity of observing the contour of the felsite, and leads to the contact of the felsite with the Seine series near the top of the ridge. The character of the felsite should be noted in order that the pebbles in the conglomerate may be compared with it, and the contact, which is located by red flags, should be followed a short distance to observe the nature of the basal conglomerate.

Irruptive Contact of the Laurentian with the Keewatin.—The white flag route is followed for a short distance to where it is joined by another road from the west. At this point, a series of green flags marks

the Laurentian Keewatin contract. The exposures are not good, but the two formations may be observed within five feet (1.5 m) of each other, and fine-grained dykes may be seen traversing the felsite. Near the contact the granite is characterized by a comparatively fine-grained texture. On the main road from Mine Centre to Shoal lake, the granite holds angular inclusions of the nearby Keewatin rocks.

Unconformable Superposition of the Seine Series upon the Laurentian.—A few yards farther along the white flag route, the contact of the Seine and older rocks crosses the road. To the right (southeast) the contact of the basal conglomerate with the granite is marked by brown flags. The lower 15 feet (4.6 m) of the conglomerate is composed of a yellowish grit, or arkose, formed by the disintegration and re-cementing of the granite. The two rocks are notably similar. At a short distance from the contact the granite assumes its normal pale pink colour and granitic texture. By walking 200 feet (61m) southeast along the unconformity the relations and characters of the two formations may be observed more fully.

A few quotations from Dr. Lawson's report (**6**) will serve to draw attention to some of the salient features:—

"The bottom portion of the conglomerate formation, while very clearly detrital, is neither water-worn nor far transported. The fragments which compose it are regular detritus of a desert alluvial slope. Where it rests upon the granite, the detritus is nearly all derived from the underlying granite, blocks of granite being enclosed in a coarse quartzitic arkose matrix; and where it rests upon the nearby Keewatin, it is nearly all derived from the underlying rocks of that series, but with considerable quartz in some parts of the matrix. This facies of the accumulation is very evidently the same as that described elsewhere under the name of fanglomerate.

"Since the fanglomerate is without doubt a subaerial formation it grades up into a conglomerate in which the boulders and pebbles are well water-worn, it seems a fair inference that the conglomerate represents a gravelly flood-plain rather than the beach of a trangressing sea. If this be true, then in a general way the distribution of the conglomerate as outlined on a general geological map of the region indicates the course of a river."

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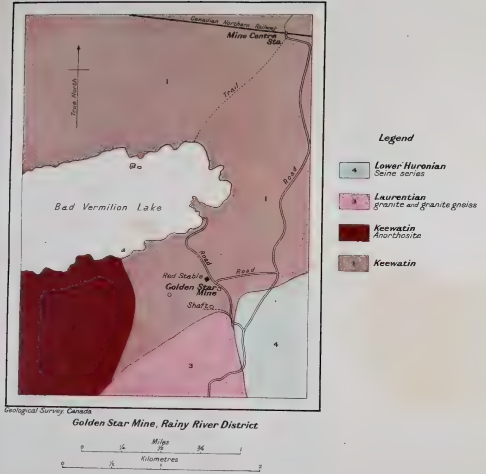


Golden Star Mine, Rainy River District

This unconformity should be compared with the Laurentian-Steeprock contact visited at point No. 2.

The Anorthosite and its contact with the Keewatin.—This contact is exposed on the south shore of Bad Vermilion lake about half a mile (0·8 km.) west of the Golden Star mill.

Dykes of anorthosite may be seen cutting the Keewatin and small areas of the coarse-grained variety are exposed near the end of the trail which leads to the top of the ridge.

The Golden Star Mine.—The Golden Star mine resulted from a prospectors' "rush" in Rainy Lake district eighteen years ago. A well-equipped surface plant was installed and underground workings totalling 3,500 feet (1,065 m.) were carried to a depth of 537 feet (163 m.). The ore body, which was a quartz vein associated with aplite dykes, carried values chiefly in gold, with small amounts in silver and copper. The gangue was principally aplite and ferrodolomite. All operations ceased thirteen years ago (1900) and the plant was burnt in 1910 (**16**).

ANNOTATED GUIDE.

(Mine Centre to Bear's Pass.)

Miles and Kilometres.

After leaving Mine Centre, the railway follows the south shore of Turtle lake, and proceeds almost due west for about 12 miles (19·3 km.). The country is flat and, to a large extent, swampy. Occasional exposures of Keewatin rocks, greenstone, diabase, and green schist, may be seen. A short distance north of milepost 195 is the location of the Olive gold mine, a glimpse of which may be caught from the train. The mine is an old one, having been opened up at the time of the Rainy Lake gold rush, but is at present inactive. A drift-covered area of Keewatin rocks extends to about mileage 200·5 (323 km.).

200·00 m. **Farrington**—Altitude 1,154 ft. (352 m.).
322·0 km. In this neighbourhood rock exposures are rare. Hills of the basement complex may be seen here

Miles and Kilometres.

and there in the distance. Half a mile (0·8 km.) west of Farrington an area of Algoman biotite granite gneiss, which continues to Bear's Pass, is entered. The country underlain by this formation is generally more rugged than the previous 20 miles (32 km). A short distance west of milepost 207, Keewatin rocks are again seen, but the contact with the granite gneiss is not visible in the immediate vicinity of the railway.

207·3 m. **Bear's Pass**—Altitude 1,143 ft. (349 m.).
333·8 km. From this point a trip five hours in length is taken in boats around the shores of the eastern arm of Rainy lake for the purpose of examining the Coutchiching series, and observing its relations to the Keewatin and the Algoman granite and syenites.

THE COUTCHICHING SERIES ON RAINY LAKE

General Description.

The Rainy Lake area affords a typical example of the rocky lake topography of the Pre-Cambrian shield. It is part of that region investigated by Dr. Lawson in 1885–1888 (**5**). The geology of this area was revised by the same investigator in 1911, certain important changes in correlation being rendered possible by the improved accessibility of the country and by the more advanced state of knowledge regarding Lake Superior geology in general. The following descriptions and review of the geology are based on the results of his recent work (1911) (**6**). The geological sequence of the rocks exposed is given below in descending order:

Archæan	Algoman	
	—*Irruptive contact*—	
	Hornblende gabbro (Keewatin ?)	
	—*Irruptive contact*—	
	Keewatin	Ontarian
	Coutchiching	

Coutchiching.—This group of rocks consists of mica schists, feldspathic mica schists, and evenly-laminated,

fine-grained gneisses. Their character throughout the area is remarkably uniform. They are believed to represent in a highly anamorphosed condition the old sedimentary crust through which the Keewatin igneous rocks were erupted and poured out as flows.

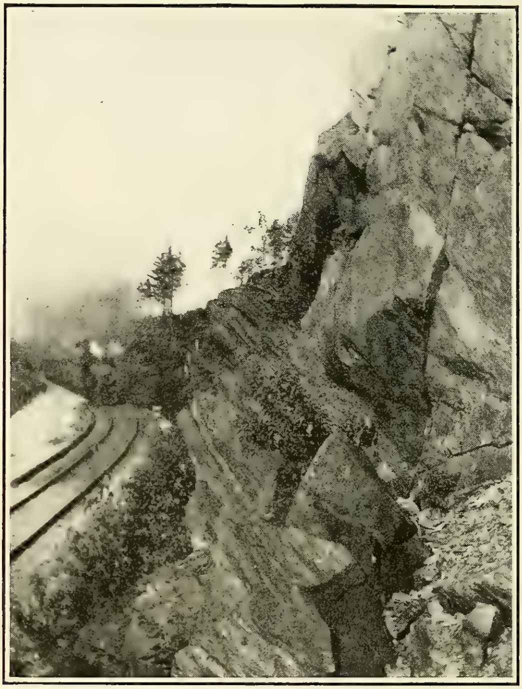
Keewatin.—The basic types, gabbro, diabase, diorite, basalt, tuff, and their schistose equivalents predominate in this district. They are metamorphosed to variable degrees, some of the gabbros and diorites being quite unaltered.

Hornblende Gabbro.—Thick sill-like masses of a rather schistose gabbro occur in association with the Keewatin series. The predominant femic mineral is hornblende, but large idiomorphic crystals of basic feldspar are abundant. Contacts with the Keewatin are exposed at a number of localities, where the gabbro is seen to be clearly intrusive into the Keewatin. The fact that it is wholly confined to the Keewatin area suggests that the intrusion is a sill or sills injected into the Keewatin prior to its deformation and metamorphism.

Algoman.—This group consists of medium-grained biotite granite and granite gneiss, with less important areas of mica syenite, and mica syenite gneiss, which have in this district developed a remarkably basic facies. On account of the warm flesh to pink colour of the granite, of the fresh biotite it contains and of the marked contrast in the general appearance of the rock, with the highly sheared Laurentian granites of Rice bay and other localities, Dr. Lawson identifies this group with the Algoman.

Structure of the Area.—The stratigraphical relations of the Coutchiching, Keewatin and Algoman groups are well exposed on the shores of the lake, and may be seen at different points along the route. An examination of the strikes and dips of the Coutchiching as platted at different points on the map shows that the formation is in the shape of a large symmetrical anticline with the axis striking N.E.-S.W. Locally around bosses of granite, the anticline approaches a dome in form, with the planes of the Coutchiching dipping on all sides away from the granite. The gradual passage of nearly flat-lying beds along the anticlinal axis to more steeply dipping ones vanishing under the Keewatin belts on the east and west shores, may be easily traced. No unconformity, other than an abrupt transition from the distinctly igneous rocks of the Keewatin

to the uniformly micaceous gneisses and schists of the Coutchiching, is present at these points. The transition marks a decided change in the conditions of rock formation.



Coutchiching mica schists dipping beneath Keewatin greenstone, Rainy lake, Ontario.

The irruptive nature of the Algoman-Coutchiching contact may be observed at several points to be visited. In proximity to the contact, inclusions of previously schistose Coutchiching are surrounded by the biotite granite, while apophyses of the granite invade areas of Coutchiching. In such localities, certain beds of the Coutchiching are abundantly supplied with secondary aluminous silicates.

It is interesting to note that the figures which represent the dips of the bedding planes away from the granite

bosses agree with the attitude of the contact plane between the granite and the Coutchiching schists, this contact being exposed in the face of cliffs that have various salients and re-entrants. The anticlinal form of the mica gneisses and schists is due to the intrusion of the Algoman batholith which has simply arched them over itself to form a roof. Dr. Lawson's conclusion is stated thus: "The Coutchiching rocks are disposed in an anticline domed around an intrusive mass of granite, and they pass on both flanks of the anticline beneath the Keewatin".

PARTICULAR DESCRIPTION OF POINTS TO BE VISITED.

After leaving the train at Bear's Pass the route around the shores of the lake follows in numerical order the small numbers, 1 to 32 on the map.

From the station to 1, a partial cross-section of the Keewatin, is exposed. The strike and dip of the schist and the nature of the coarse-grained gabbro can be observed Going southward along the shore between 1 and 2, the transition from Keewatin hornblendic and chloritic rocks to Coutchiching micaceous schists, with about the same strike and dip, may be seen, the latter dipping beneath the former. From 2 to 4 the irruptive contact of the Algoman biotite granite and the Coutchiching is well exposed; the long narrow point at 3 affords a splendid view of the contact breccia. The granite is pale pink to white in colour, and somewhat fine-grained. The shore line in this vicinity shows alternate outcrops of Algoman and Coutchiching.

A landing is made at 4 to examine the contact between the Coutchiching and the Keewatin. Here the micaceous schists are markedly quartzitic and are beautifully plicated. The contact with the rather massive Keewatin greenstone is sharp, and the Coutchiching dips rather steeply under it.

From this point in a westerly direction to 8 an excellent section is obtained across the Coutchiching formation almost at right angles to the anticlinal axis. The shore is followed closely, so that the attitude of the Coutchiching beds may be noted. The steep southeasterly dips of the formation to the east gradually flatten, until in the neighbourhood of 5 and 6 they are nearly horizontal or locally buckled. Here the locus of the anticlinal axis is reached.

From 5 west, the dip is in the opposite direction, that is, to the northwest, and gradually increases to 45° or 50° The steep dips of 60° to 75° on the eastern limb of the anticline are nowhere seen on the western limb. Along the shore near 7, the nature of the formation at a distance from the intrusive granite and the attitude of the beds are exposed to advantage.

From 8 to 9 the contact between the Coutchiching and the Keewatin can be traced approximately. On the left hand side the mica gneisses and schists, dipping from 25° to 45° towards the northwest, are well exposed. On the right, the islands numbered 26, 25 and 22 consist of typical Keewatin formations.

From 9 through Bear's Passage to 13, another section is made across the anticlinal axis of the Couchiching. Generally speaking, the dips change from northwest to southeast through an intermediate, approximately horizontal attitude. The intrusive granite, which is exposed in actual contact with the Coutchiching from 10 to 11 is a disturbing factor in this section. Near its margin, the mica gneisses and schists strike roughly parallel to the contact, and in all cases dip away from the granite boss, as if they had been arched over its surface at the time of the intrusion. A gradual increase in the angle of dip is observed from 12 to 13, until, at a maximum of about 70° to the south-east, the Coutchiching disappears under the more massive rocks of the Keewatin. The actual contact is not exposed here.

From 13 to 14 a belt of Keewatin schist with a steep southeasterly dip is crossed to another band of Coutchiching, also dipping steeply to the south east. This Keewatin belt is interpreted as the eroded remnant of an appressed synclinal trough, overturned towards the southeast, and pitching to the northeast. In this second or Shelter Cove belt of Coutchiching, the series is represented by quartz slates rather than the metamorphic mica schists. At 15 a good exposure of the Coutchiching in an almost vertical attitude may be seen. Farther east, it passes again under the Keewatin.

The course now leads directly to Bear's Passage and along the left hand shore from 16 in a northwesterly direction. An almost continuous outcrop of Algoman granite with large inclusions of mica schist follows the shore to beyond 17, and may be observed in passing.

The granite-Coutchiching contact is crossed between 17 and 18. At the latter point, there is a good exposure of a basic facies of the Algoman syenite intruding the Coutchiching, which dips away from it on all sides. The contacts are well exposed.

The shore line is closely followed to the railway crossing, and typical exposures of Coutchiching, abundantly supplied with secondary crystals of the aluminous

Inclusions of Coutchiching mica schist in Algoman granite, Rainy lake, Ontario.

silicates may be seen from 19 to 20. At 20 the mica schists clearly dip under the Keewatin. At 21 is a small exposure of a conglomerate-like rock associated with the Keewatin.

The island at 22 consists of Coutchiching garnetiferous schists dipping at 20° to the northwest. By landing at the north end, an excellent opportunity is afforded to observe their attitude with respect to the Keewatin group which underlies the island (23) immediately to the north.

From 24 to 27 are exposures of a hornblende gabbro showing phenocrysts of basic feldspar. The contacts of this formation with the Keewatin are not conveniently exposed on the shores of the lake.

From here, the shore line is followed rather closely in a northerly direction to 30. Apart from small areas of Coutchiching at 28 and 29, the exposures consist chiefly of Keewatin medium-grained, massive to schistose diorite. At 30 the Coutchiching schists again pass beneath these.

The lake is now crossed in an easterly direction to 31, where a landing is made to examine the excellent contact breccia of Coutchiching and Algoman there exposed. The inclusions of previously schistose Coutchiching enclosed in the invading granite, as well as the apophyses of the latter cutting the former may be noted. A small area of nearly flat-lying mica schist between 31 and 32 represents a remnant of the roof of the batholith. At 32 a striking exposure showing horizontal jointing in the granite may be seen from the boats. Just north of 1 another Keewatin-Coutchiching contact might be advantageously examined, after which a return is made to the station.

ANNOTATED GUIDE (Bear's Pass to Winnipeg).

Miles and Kilometres.

From Bear's Pass station the railway runs along the western edge of the Keewatin synclinal trough, described above, to 4, where it enters the Coutchiching and pursues a course across the latter nearly at right angles to the anticlinal axis. The more or less flat-lying Coutchiching beds in the cuts between mileposts 209 and 210, represent remnants of the batholith roof. After crossing the narrows northeast of Bear's Passage the railway passes again into Keewatin, intruded by hornblende gabbro. Leaving this, another Coutchiching belt is crossed between mileposts 212·5 (342· km.) and 214 (344·3 km.), beyond which the

Miles and Kilometres.

Keewatin again outcrops, and with intrusions of the gabbro continues to milepost 222. The gabbro-Coutchiching contact is followed somewhat closely to mile-post 224, where, near the westerly end of the Rainy Lake crossing, the railway passes into the Algoman granite.

After leaving the lake, the alluvial plain country is entered and only occasional outcrops are visible. The eastern boundary of the bed of glacial Lake Agassiz (**12**) has not been very accurately located, but it is believed to be near the eastern edge of Rainy lake. The lake deposits may be seen almost continuously to Winnipeg, although the sands and stratified gravels have been rearranged in places to form part of the alluvial plain of Rainy river.

231·3 m. **Fort Frances.**—Altitude 113 ft. (340 m.).
372·3 km. The bed-rock from Fort Frances westward to Winnipeg is almost unexposed. From the occasional outcrops that do occur, and from the small mining operations carried on in the region, it is believed that the country is under-
286 m. lain (Rainy river) chiefly by rocks of Pre-Cam-
460 km. brian age, at least as far west as the Manitoba boundary The description by Dr. Lawson (**6**) of an exposure of possibly Richmond fossiliferous limestone (Ordovician) about six miles (9·6 km.) west of Fort Frances is interesting, as it may prove to be an outlier of the Palæozoic of Manitoba.

324 m. **Warroad.**—At Beaudette the railway crosses
521·4 km. the International Boundary line into United States territory, through which it runs for about 35 miles (56 km.), crossing back into Canada a few miles beyond Warroad.

439 m. **Winnipeg.**—Altitude 760 ft. (231·6 m.).
706 km.

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ORDOVICIAN AND SILURIAN OF STONY MOUNTAIN AND STONEWALL, MANITOBA.

BY

A. MacLean.

ORDOVICIAN—STONY MOUNTAIN.

The Teulon-Arborg branch of the Canadian Pacific Railway runs in a northwesterly direction from the city of Winnipeg 11 miles (17·7 km.) to Stony Mountain, and thence continues to Stonewall about 6 miles (9·6 km.) beyond.

On leaving Winnipeg, Stony Mountain may be seen rising apparently abruptly from the flat lacustral plain through which the train passes. The flatness of the country is emphasized when it is remembered that the "mountain" is 11 miles (17·7 km.) distant and rises only 50 feet (15·2 m.) above the surrounding country.

Between Winnipeg and the "mountain" no rocks outcrop and, save for the flatness of the lacustral plain, there are no features of physiographic or geological importance. The country is given over to mixed farming, and the production of dairy supplies for Winnipeg.

On approaching Stony Mountain, the hill is seen to the right of the railway. The west and north sides have abrupt faces, while on the south and east the hill slopes gradually away to the plain.

The Manitoba penitentiary stands on the brow of the hill nearest the railway station, while to the north and east of it are two quarries at present in operation. The magnesian limestones quarried here are of upper Ordovician age.

These quarries may be easily reached from the spur which leaves the railway about a mile north of the station and runs to the front of the quarries. In the quarry belonging to the city of Winnipeg is a good section which shows all the strata outcropping elsewhere over the mountain.

Though the beds are apparently flat, they have a slight dip to the southeast of 2 or 3 degrees. This attitude is in part responsible for the contour of the "mountain," with its sharp face toward the north and west, and gentle slope to the south and east. Glaciation has, however, accentuated this by developing a "crag and tail" topography by stripping the northern and western fronts and piling the debris thickly in the lee of the hills to the south and east.

On the top of the mountain glacial material is very scant, varying from a few inches to a few feet in depth. This rests on the upper limestone of the quarries, which, in most cases, shows scored and striated surfaces when freshly stripped. Below this a buff magnesian limestone is quarried for a depth of 12 or 14 feet (3·6 to 4·2 m.), when beds of yellowish brick-like shale are reached. These beds are 14 feet (4·2 m.) in thickness and rest on a reddish shale interlaminated with thin layers of limestone. The various beds exposed in the vicinity of the mountain comprise the "Stony Mountain" formation (**3**) which is composed of three main divisions: (**A**) an upper magnesian member about 12 feet thick in which the quarries are located and which contains a very meager fauna including several Beatriceas from the size of a cigar up to four inches in diameter and a foot in length, together with brachiopods and occasional corals; (**B**) a middle member about 15 feet thick consisting for the most part of a massive yellow brick-like shale which is almost filled in places with the casts and moulds of corals, bryozoans, brachiopods,

pelecypods, gastropods, cephalopods, and trilobites, a score or more of species having been identified; and (C) an exposed thickness of 12 feet of alternating thin limestone bands and red shale, the limestone layers bearing upon their weathered surface an even greater assemblage of fossils than were mentioned for the middle member, over fifty species having been identified, as follows: 5 corals, 1 crinoid, 17 bryozoans, 8 brachiopods, 8 gastropods, 3 cephalopods, 9 ostracods, and 3 trilobites. The interlaminated shale crumbles readily and specimens of corals, brachiopods, and bryozoans can be picked up from its weathered slopes. The detailed section of the beds in descending order is as follows:

	Mantle rock.—Glacial till, consisting of sand, gravel, and boulders, local and "foreign", with some clay and surface layer of soil.	2 inches to 5 feet, 5 to 15·2 cm.
A	1. Limestone.—Hard, white in colour, showing few or no fossils. In some places this has been stripped from the top of the quarry. .	24 inches, 61 cm.
A	2. Limestone.—Hard, white in colour, breaks into 5 or 6 layers of irregular thickness. Surface may weather porous. Fossils not evident....................	14·5 inches, 37 cm.
A	3. Limestone.—Rusty, yellow, joint faces. No fossils................	32 inches, 81 cm.
A	4. Limestone.—Compact, yellow, often shows coarse porous structure.........................	40 inches, 102 cm.
A	*5. Limestone.—Yellow, with porous bands near top and bottom.	59 inches, 150 cm.

* Beds 2 to 5 constitute the quarries as they are usually worked. Fossils are not entirely absent, but the perfection with which the fossil is merged in the rock and the uniformity of both in texture and composition renders it difficult to detect them. In rare cases they are exposed by weathering in the quarries, the most striking of these fossils being the Beatriceas, which attain a diameter of four inches and a length of a foot or more.

B	6. Arenaceous shale.—Brick-like in texture, varies in colour from yellow to purple. Carries fossils of gastropods, brachiopods, corals, etc.	10 inches, 25 cm.
	7. Calcareous shale. — Yellow, brick-like, showing in some localities fossils, generally as casts or moulds	60 inches, 152 cm.
	8. Calcareous shale.—An irregular bed, weathering readily to a nodular mass, although in some places more compact. Few fossils	36 inches, 91 cm.
	9. Calcareous shale.—Yellow, brick-like, very much like No. 7. Contains fossils, corals, bryozoans, brachiopods, gastropods, etc.,	66 inches, 168 cm.
C	10 Shale.—Red, loose in texture, weathering readily to a crumbling mass. Interlaminated with limestone beds about 2 inches in thickness. Both limestone and shale are quite fossiliferous, bearing corals, bryozoa, brachiopods, gastropods, cephalopods, ostracods, and trilobites	144 inches, 366 cm.

The beds exposed in this section are believed to represent the Richmond and possibly the Lorraine formations of the Ohio Valley. Good sections of the lowest shale of the above section can be obtained in abundance.

This lowest shale is the best of the series for the collection of fossils, and is exposed at several places over the mountain. One of these is to the south of the Winnipeg city quarry, and just below the Manitoba quarry, near their old lime kiln. Two other exposures are on the prison reserve: one in the prison gravel pits in the face of the hill opposite the main buildings; the other a short distance to the southeast of this and in the same face of the same hill.

The shale above this (Nos. 7, 8, and 9 of the above section) is best exposed for collecting purposes in the cut on the east and west road to the north of the prison reserve, where 16 feet (4·8 m.) of thin bedded shaly limestone are exposed. Fossils occur here abundantly and include *Favosites aspera*, *Cyathophyllum* sp., *Platystrophia biforata* var. *lynx*, and *Rhynchotrema capax*. An occasional massive specimen of *Favosites aspera* may be seen in the basal beds of the quarry immediately north of the village. These sometimes have a diameter of 12 to 15 inches (30 to 38 cm.).

As already mentioned the beds which are quarried, yield but few fossils. Such as do occur may be best seen in some of the abandoned quarries, where weathering has assisted in bringing out an occasional one. Such a quarry is to be found directly east of the Manitoba Company's quarry, to the south of the road allowance which passes between the two quarries.

Beneath the light covering of till, the surface of thin limestone has been beautifully polished and striated in a direction S 20° E, furnishing evidence of the latest advance of the Keewatin glacier from the north and northwest. The Labradorian glacier from the northeast also reached this hill at a later period, but the striae left by it, being about southwest, are not abundant, as the older till protected the underlying rock. On the brow of the eastern side of the mountain, however, is a little ridge six feet (1·8 m.) high of angular blocks of limestone which may be a morainal accumulation shoved up by this glacier.

On the opposite side of the hill is an old gravel beach of Lake Agassiz, and in the head of the horseshoe-shaped summit is another lower beach.

SILURIAN—STONEWALL.

Between Stony Mountain and Stonewall there are no rock exposures along the line of railway. The country continues quite flat, but between the two stations there is a rise of about 50 feet (16·7 m.), Stony Mountain being 777 feet (235 m.) above sea level, and Stonewall being 826 feet (251·7 m.).

Just before entering Stonewall a test pit may be seen on the south side of the railway. On the north side, spurs lead to the quarries of the Manitoba Quarry Company.

Passing through the station, the track takes a semicircular course about the west side of the town, and turns in an easterly direction along the north side of the quarry operated by the Winnipeg Supply Company. In this quarry, the deepest cutting has been made and the best section is to be seen.

The strata are only exposed in the quarries, being elsewhere covered to a depth of 2 to 12 feet (.6 to 3.6 m.) Below this the surface of the rock is generally deeply scored, but in most cases the glacial polish has been removed, in all probability by the solvent action of surface waters. The rock is generally quarried to a depth of 12 or 14 feet (3.6 or 4.2 m.) below the topmost bed. When quarried it is used for crushed stone, rubble, and also for lime, for which it is eminently suited. The floor of the quarry is of red shale some 15 inches (38 cm.) in thickness, below which is six feet (1.8 m) of limestone in two beds. This is very hard, darker in colour than the limestone above, and is unsuitable for lime. Below this is a dark red shale which continues in depth below the level now exposed.

The section in descending order is as follows:—

A.	Soil and non-assorted material. Boulder clay or till of variable depth.		
	Stratified material.—Alternate layers of sand and shale, one inch to one quarter inch in thickness. Shale is well assorted. Sand layers are poorly assorted. No fossils	16 inches,	41 cm.
	Boulder clay or till, lying on surface of rock which is scored and striated	33 "	84 cm.

B.	Limestone, light colored and magnesian representing the uppermost course of quarry which in many cases has been removed..	60 inches	152 cm.
	Limestone of the second course. Hard, massive, and very similar to the overlying bed from which it is distinguished only by difference in thickness. Both these courses contain a tabulate coral, generally poorly preserved except in one locality, to which reference will be made later........	41 "	104 cm.
	Limestone. This is the lowest course generally quarried. Less massive than either of above, quite often breaking into laminae 2 to 10 inches (5 to 25cm.) in thickness........................	48 "	122 cm.

In one portion of this quarry operations were at one time continued below this, revealing the following:—

C.	Shale, red and nodular in character. The individual nodules are fairly hard, but the mass does not form a consistent bed..	15 inches,	38 cm.
D	Limestone, yellowish in colour, hard and porous, probably magnesian. The pores are large, resulting probably from weathering out of fossils or other more soluble content. Tabulate corals and cephalopod remains occur in this layer..................	31 "	79 cm.
	Limestone, similar to above, but lower half is darker in colour, and has much finer pores, uniformly distributed. Forms the "freestone" of this level............	41 "	104 cm.

A test pit sunk at one corner of this part of the quarry shows other layers below this as follows:—

E.	Clay-like shale, fine grained, white in colour......................	6 inches,	15 cm.
	Bright red shale, breaking by irregular fracture to a mass of small angular particles. This bed is here exposed for 36 inches (91 cm.), and is reported to have a total thickness of............	6 feet,	183 cm

Below this is said to lie seven feet (201 cm.) of freestone, but whether this is a hard porous dolomitic limestone or a true sandstone could not be determined. It is probably the former.

The strata at this place contain few fossils. The beds below those indicated "A" to "C' are exposed only in this quarry and contain few fossils. The fossils from the upper limestone occur in more abundance in an old quarry of the Manitoba Quarry Company, a little to the south and east of this one. In this place they occur quite freely in the walls, and in the rubble scattered over the floor of the quarry. Although the spicies are few, the specimens occur in large numbers and are well preserved. This quarry is reached by going east on Higgins street or Drake street, or by entering from the railway spur, previously mentioned, from the main line to the east of the station.

The most common species occurring here are *Favosites aspera*, *F. gothlandicus*, and *Plectambonites*?, sp. undet. Other species occurring here include *Aphyllostylus gracilis*, *Trimerella* sp. undet., *Dinobolus* cf. *conradi*, and several species of gastropods and cephalopods. The new cephalopod, *Sphyroceras meridionale* Whiteaves and *Cyrtoceras cuneatum* Whiteaves and a new genus of corals *Aphyllostylus* have been described from material collected in the Stonewall quarries. (**4**).

The fauna is of Silurian age and is probably the equivalent of either the Guelph or Lockport. It represents a faunal province distinct from that of Ontario and Western New York, which makes precise corralation with the New York section impracticable.

The beds in the quarry walls appear horizontal, but those in the floor of the quarry show a distinct dip. In one case this is 2 or 3 degrees in a direction almost due south; in another case, one quarter mile distant, the dip is 2 or 3 degrees in a direction due west. The general dip over all the quarries is toward the southwest.

Grooves and striae trending S 20° E, made by the Keewatin glacier, may be seen on all fresh surfaces, while here and there some striae of the Labradorian glacier may be detected running N 80° W.

The presence of the stratified and partially assorted layer between the two boulder clays is indicative of a temporary recession of the ice, although the thinness of the layer and the absence of organic remains would suggest that it was probably local and of short duration.

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WINNIPEG TO BANKHEAD.

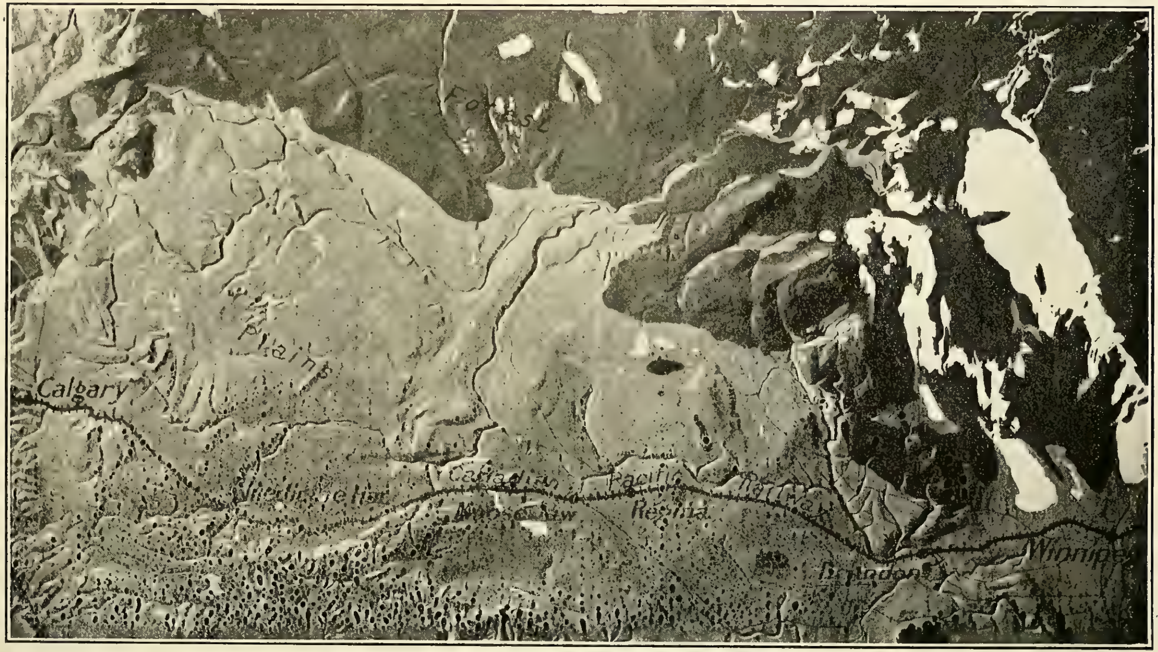
BY

D. B. Dowling.

INTRODUCTION.

THE GREAT PLAINS.

The central part of the continent to the east of the Rocky Mountains is generally referred to as the Great Plains. This name, as applied to the southern portion of the region, is descriptive mainly of its treeless character.



The topography of the plains, Winnipeg to Calgary.

It is however not without variety in its topography since a large part of it is a northeasterly sloping plateau of Mesozoic sediments etched into somewhat irregular surface contour, and overlapping a lower plain having the irregular features of the great pre-Cambrian shield.

In the belt traversed by the railway lines, a threefold division of prairie steppes rising one above the other to the west is clearly recognizable, though the term prairie may not be applicable farther north. These three divisions are here adopted for descriptive purposes and a fourth is added to include the broken, hilly country of the foothills.

The first and eastern division comprises the plain east of the Cretaceous deposits which rise as a low escarpment to form the plateau. The second extends from the edge of this plateau westward to the erosion remnants of former Tertiary deposits and the third from this line westward to the foothills.

First Division.—This division is the lowest in elevation and is essentially a region of lakes, with the exception that in the southern part the inequalities of the rock surface have been smoothed over by the deposition of clays and silts in glacial Lake Agassiz. This forms the rich farming country of southeastern Manitoba, where the extreme evenness of surface is noticeable because of the general absence of timber. This plain is however being partly forested by the individual efforts of the farmers.

The surface features east and north of Lake Winnipeg differ from those to the west in having the mammillated character typical of a region underlain by Pre-Cambrian rocks with but a thin mantle of drift. The large lake basins are due mainly to the removal of Palæozoic rocks from the older westerly dipping rock surface.

Traces of the margin of glacial Lake Agassiz remain in distinctly marked beaches resting on the slopes which rise upward to the Cretaceous plateau.

The railway ascends to the Cretaceous plateau up the wide delta and valley of the ancient Assiniboine river, where it entered Lake Agassiz. The present drainage of this region is northward to Hudson bay by Nelson river.

Second Division.—This division is the lower or eastern portion of the plateau and is underlain by a succession of shale beds and other equally soft rocks. The surface is about 1,000 feet (304 m.) above the Manitoba lakes or

1,800 feet (545 m.) above sea level, but is not a uniform plain. Several deep valleys traverse it, one of which was incised by the water of the South Saskatchewan river, at a time when the northward flow of that stream was blocked by glacial ice. This channel is now occupied by a small stream called Qu'Appelle river. Streams flowing eastward across the plateau have cut deep valleys into the escarpment which rises from the lower prairie level to the east and have left remnants standing as isolated hills which are known as the Pembina, Riding, Duck, and Porcupine mountains.

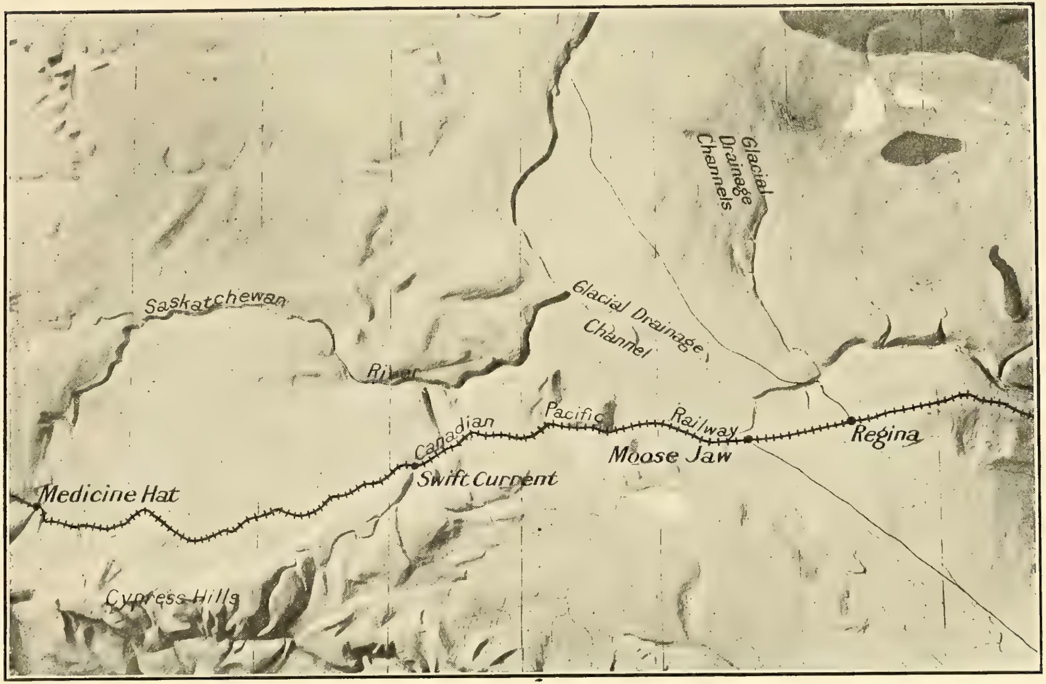
The drainage is eastward into a confluent series of streams entering the Assiniboine valley and northeastward into the Saskatchewan. Wooded areas occur in the north and along the outer edge of the plateau, while a few of the higher levels of the central surface are similarly covered.

Third Division.—This area, extending from the Coteau, or the hilly country just west of Moosejaw, to the foothills of the Rockies, is divided by the depression through which the South Saskatchewan river flows. To the north of this depression the drainage is mainly eastward to the North Saskatchewan, while the region to the south includes a fringe of the drainage basin of the Missouri river. There is also immediately west of the Coteau a small basin without outlet whose waters evaporate in Lakes Johnston and Chaplin.

The relief in this division is accentuated by the fact that much of it is bare of trees, so that such elevations as the flat topped Cypress Hills standing 2,000 feet (608 m.) above the railway near Medicine Hat or the Hand Hills 800 feet (243 m.) above the surrounding plains, become prominent topographical features.

Fourth Division.—The topographic character of the foothills is much more diverse than that of the other divisions. The geological structure is closely related to the topography, and all the hills are formed of folded or faulted rock masses.

Since the folding in these hills is due to the same causes that produced the Rocky mountains, the strike of the folds follow directions nearly parallel to the mountain chain. Although often of considerable elevation the summits of the foothills are not as serrated as the mountains, since the rocks composing them are of softer materials. Their flanks also are either grassed or clothed with



The eastern edge of the third Prairie Steppe and the Glacial drainage channels on the second Prairie Steppe.

timber. The general arrangement is a belt of varying width and elevation consisting of parallel ridges cut here and there by streams rising in the mountains behind.

ROCKY MOUNTAINS.

On the basis both of form and of structure the Rocky Mountain system is divisible into two parts:—a western, and an eastern part. The axial ranges constituting the western part have been carved from a slightly folded but greatly elevated block, the denudation of which was probably inaugurated before the eastern ranges were elevated. The eastern part is made up of monoclinal blocks, the beds of which they are composed being generally younger in age than those of the western part of the mountains.

Outer Ranges.—As topographic features these ranges are in a general way merely blocks more elevated than those of the foothills, from which nearly all the younger soft series of rocks have been removed, exposing the more consolidated Palaeozoic sediments beneath. The fault blocks are, as a rule, tilted westward, and along their eastern scarped faces remnants are often found of the anticlines which were broken near the crest, showing that these blocks were the western limbs of folds overturned and broken. The plane of the overthrust faults is frequently inclined at a comparatively low angle indicating that the thrust was from the west. The outer fault is often of this character, and the overthrust, although great in Montana, becomes modified in the Canadian ranges and decreases northward. In southern Alberta the Palaeozoic rocks of the watershed range on the British Columbia boundary line overlap the Cretaceous beds of the western part of the fault block, forming the Livingstone range; and Crowsnest mountain, which is an erosion remnant of Palaeozoic superposed upon Cretaceous rocks, stands as an example of this overthrust. The westward slopes of of these fault blocks depend to a great extent on the dip of the beds, so that a similarity in outline of their slopes is repeated along the range. The eastern slopes are often more abrupt, and their form depends largely on resistance of the strata to erosion or a disposition of fractures. Local glaciers have, moreover, etched this face into cirques and thereby contributed to the irregularity of the crest line.

The Western Rocky Mountains.—In contrast to the outer or eastern ranges, the mountains near the watershed stand in isolated peaks, carved from a large block of older rocks. Less folding and fewer faults occur. More massive bases and higher summits, to which cling many glaciers, give a more Alpine aspect to the scenery. Small cirques, such as the gap called White Man's pass at Canmore, in the outer mountains, give place in the inner ranges to great amphitheatres such as those in the vicinity of Laggan.

The first appearance of this part of the Rocky Mountain system may have occurred shortly after the Jurassic sediments were laid down, and then only as low ranges. Periods of subsidence and elevation may have followed and recurred throughout Cretaceous times.

HISTORICAL GEOLOGY.

The wide depression, in which the sediments of the central part of the continent were deposited, was at its greatest marginal extent probably in Devonian time. Earlier deposits appear on the southeastern margin and again in the mountains to the west.

A great series of ancient sediments, some probably Pre-Cambrian in age, is found in the area occupied by the western part of the Rocky mountains and the adjoining ranges to the west. This thick series shows in its upper part the existence of marine conditions during Cambrian time. The downwarp, which was here partly filled by coarse sediments, may not have extended far to the east from the continental margin of that time, and was probably separated from the main ocean by a barrier. A general subsidence before the close of the Cambrian is indicated by patches of rocks of this age on other parts of the continental area. Deep sea deposits, magnesian limestones of the Castle Mountain series, were formed before the recovery of elevation which closed the period.

Considering only the area east of the Rocky mountains, it is not clear, that during Ordovician time, the marine invasion shown by the character of the sediments at the top of the Castle Mountain series was other than by an arm of the Pacific. In the eastern part the invasion from the south in early Trenton time is marked by the deposition

of limestones in the Lake Winnipeg basin. A more general submergence during Devonian time is represented by beds of magnesian limestone which are exposed along the foot of the Cretaceous escarpment across Manitoba and in a broad sheet northward down the Mackenzie river and in the Rocky mountains throughout their entire length. The absence of the succeeding Carboniferous deposits in the eastern part of this basin, as well as to the north, suggests a retreat of the sea westward. In the mountain region Carboniferous limestones are prominent in southern Alberta, but northward these thin out and are replaced by sandstones and shales.

A farther retreat during Permian and Triassic time, during which sandy and shaly deposits were laid down, is indicated in a thin series of these rocks in the mountains. They extend northward to Stewart river in the Yukon, and prove that with the shallowing of the Carboniferous sea there was also transgression northward.

The crustal disturbances of Jurassic time in British Columbia were reflected in the inauguration of another downwarping movement that produced a narrow trough in the belt now occupied by the Rocky mountains. This permitted the entrance of the sea from the north across northern British Columbia. The deposits carried to this basin in general went to form fine grained black shales. Sandstone members appear in the lower part at intervals, but generally the source of the material is believed to have been at some distance. In northern British Columbia volcanic ash is intercalated with the sediments, and volcanic outflows are found on what were probably land areas.

At the close of the Jurassic, sedimentation became periodically rapid. Sands were washed into the basin and the surface elevation was maintained at or near sea level, so that the continental drainage replaced the saline water in the basin. Land areas were maintained for long periods during which coal seams were formed from the vegetation. This period, which is generally ascribed to the Lower Cretaceous, was closed by a general subsidence to the east, in which the sea advanced again to cover a large part of the centre of the continent. This invasion of the sea submerged the fresh water deposits of the Dakota in the east and also spread in the central part of the basin similiar sandy beds as basal members of the marine series.

In the west the marginal beds below the marine Cretaceous sediments are as a rule fresh water deposits. The coarse conglomerates and sandstones, there found belonging to this period of extension of the Cretaceous sea, indicate some corresponding uplift in the land area to the west which increased the gradient of the slopes. The coarseness and thickness of the material contained in these beds (maximum 6000 feet, 1824 m. in Crowsnest area, reduced rapidly to the east to less than 900 feet (274 m), suggest a nearer approach to the zone in which mountain building was active, probably in the southern part of the present western Rocky mountains.

Throughout the later stages of the Cretaceous, the eastern part of the basin shows little change in the deposits which were mainly marine clays. The western part, as exposed in the deposits of the faulted zone, shows repeated subsidences and elevations up to sea level. Active denudation of the western land areas is shown in conglomerates at the top of Benton shales exposed on Bow river and northward on the Brazeau and Athabaska rivers. Conglomerates also occur in the Belly River series at Crowsnest mountain and in the north in the Brazeau fields. This material was probably eroded from the hills appearing to the west, the prototypes of the western portion of the Rocky mountains.

The periods of elevation along the western margin of the interior region with the consequent changes in deposition, while not always prolonged, appear at one stage to have been of sufficient magnitude to allow the accumulation of a large body of brackish water deposits, the Belly River series. The surface so exposed was at times covered by vegetation, and thin coal seams were formed. This was subsequently covered by the marine deposits of the Pierre stage of Cretaceous time.

The close of the Cretaceous marine invasion is marked by the brackish water beds containing the coal seams of the Edmonton formation. During Tertiary time the deposits were distributed in fresh water and this part of the continent was raised to sea level—the distribution bringing in landlocked lakes or confined estuaries. The western Rocky Mountain ridges probably did not bar drainage from the gold bearing rocks of British Columbia, since the source of the gold in northen Alberta streams is credited to the lowest Tertiary or beds at the top of the Cretaceous.

The exact date at which elevation of the Rocky Mountains commenced is not certain, but it is probable that from early Cretaceous times the crust here was under strain and that at intervals during the warping of the crust before the close of that period the western part of the range had been marked out by hills which were being denuded of their top covering of shales, quartzites, and limestones to swell the accumulations in the Cretaceous sea to the east. The period of mountain building to which the elevation of the Rocky Mountains is assigned, the Laramide revolution, is probably a long one. The formation of the outer ranges with their frequent great overthrusts eastward, was subsequent to the elevation of the ranges of the watershed or to the deposition of the early Tertiary beds of the Paskapoo formation.

The denudation of post-Tertiary times has removed most of the broken material resulting from this late revolution, but the large well rounded pebbles in the Oligocene beds of the Cypress and Hand Hills, are probably the remains of that material. This period of mountain building is probably later than the Laramie and occurred between the Paskapoo or early Tertiary and the Oligocene.

Part of the denudation of the early Tertiary and Cretaceous beds of this basin may have been accomplished at this time, especially in the part near the mountains, but the greater part was due to a general elevation in Pliocene times, when much of the area was in process of reduction. The amount of material removed is well shown on the north side of Cypress Hills, where from the level of the Oligocene deposits the Saskatchewan river is now cutting through horizontal beds that are 2,000 feet (608 m.) below. The wasting away of material from the edge of the basin was also continued and before Glacial time the plateau of Cretaceous deposits assumed nearly its present form.

Many of the present valleys are broad depressions formed in pre-Glacial time, and sometimes show old stream gravels, derived from the Oligocene conglomerates, covered by the boulder till. Glacial deposits are spread over all the area, and, almost to the mountains, hold erratics derived from a northeastern source. The Cordilleran glacial material has been carried but a short distance eastward from the mountains.

The question of the extension of the continental ice sheet is still an open one and the glacial till west of the Coteau is believed by many to have been carried by floating ice. The closing stage of glaciation was no doubt one in which the ice front held back large lake-like basins, of which the best known is glacial Lake Agassiz which occupied the basin at the eastern edge of the Cretaceous plateau. This lake at first drained southward to the Mississippi valley, and at that stage formed many beaches along its western and southern margin. These beaches show a gradual rise to the north due to an upwarp of the crust, which caused the waters to continue their discharge southward until on the retreat of the ice to the north an outlet was found in that direction. Many of the former drainage channels were ice blocked, and the lake received a large inflow from the southern part of the plateau to the west of it. As a result of the valley cutting which ensued at this time, a great burden of fine-grained material was deposited in this basin to form the lacustrine deposits of the Manitoba plains.

SUMMARY DESCRIPTION OF FORMATIONS.

ORDOVICIAN.

In Manitoba the Ordovician includes the following formations:—

Stony Mountain formation, consisting of yellowish and reddish limestones overlying dark shales. Exposed at Stony Mountain.....	110	feet	(33·5 m.)
Upper mottled limestone..............	150	"	(45·7 m.)
Cat Head limestone..................	70	"	(21 m.)
Lower mottled limestone..............	70	"	(21 m.)

The divisions of the Trenton here indicated are made on physical grounds. The exposures are best seen on Lake Winnipeg. No deposits of this age occur in the outer ranges of the Rocky mountains.

SILURIAN.

The Silurian is composed of light-coloured, thin-bedded, yellow limestones. In the region to the east of Lake Manitoba important beds of gypsum are being mined from this formation.

DEVONIAN.

In Manitoba the Devonian rocks are divisible into three series as below:—

Upper Devonian or Manitoban, consisting of light gray, hard brittle limestone, with red argillites at the base, about...........................	200 feet (64 m.)
Middle Devonian or Winnipegosan, consisting of light yellow, hard dolomite, with porous beds beneath, about...........................	200 feet (64 m.)
Lower Devonian, mainly red shales. These beds probably represent only the upper part of the lower Devonian of eastern America, about	100 feet (30 m.)

In western Saskatchewan these beds may be found near the Churchill river; having nearly the same characters.

In Alberta, the most eastern exposure is in the neighborhood of Athabaska river. In the Rocky mountains they form the Intermediate series, brownish, irregularly hardened dolomites, and greyish, crystalline dolomites, with some sandstones and quartzites.

CARBONIFEROUS.

These rocks are found in South Dakota, Montana, and Alberta. They are not exposed in Manitoba or along the northwest margin of the Cretaceous plateau, but are confined to the Rocky Mountain region. They have been subdivided on lithological grounds into upper and lower Banff limestones. These formations are each capped by shaly beds, from which have been obtained a few characteristic fossils. The formation is generally a bluish limestone, and forms the summits of Cascade and Rundle

mountains, near Banff. A thickness of over 6,000 feet (1,824 m.) for the formation has been observed in the Bow valley.

PERMIAN AND TRIASSIC.

At the top of the limestone series in the Rocky mountains, a series of quartzites overlaid by red shales may be in part Carboniferous, but as the series is conformable to the Jurassic, some deposition should be credited to Permian and Triassic. The red shales are occasionally capped by a thin band of yellowish dolomite, and often the series, on fresh exposures, shows yellow bands in the shales. Evidences of a Triassic age for the upper shales have been found in shells of *Monotis* type. These are recorded at Blairmore in the south and on branches of Brazeau river. Northward Triassic fossils have been found in Pine and Peace river valleys.

JURASSIC.

Fernie shale —In the locality where this formation received its name, Fernie, B.C., it consists of a series of black and brownish shales 1,060 feet (323 m.) in thickness overlying 500 feet (152 m.) of sandy argililtes. Eastward the series decreases in thickness. On the Cascade river the section is 1,600 feet (487 m.) and consists of black shales and grey sandstones with an occasional limestone bed toward the base. In the Moose Mountain area—an outlier of the Rocky mountains—the thickness is about 225 feet (68·5 m.). The formation has been traced northward to Athabaska river and preserves its general black, shaly appearance. Few fossils have been obtained in these measures, but they are characteristic:—*Cardioceras canadense*, *Peltoceras occidentale*, *Terebratula robusta*, *Ostrea skidegatensis*, *Exogyra* sp., *Lima perobliqua*, *Pteria corneuiliana*, *Trigonoarca tumida*, *Trigonia dawsoni*, *Astarte carlottensis*, *Protocardia hillana*, *Cyprina occidentalis*, *Pleurotonomya carlottensis*, *Schlœnbachia borealis*, *S. gracilis*.

CRETACEOUS.

Kootenay.—The lower member of this series of deposits is found resting upon the Jurassic in the Rocky mountains. In Manitoba it has not been recognized, and is

supposed to have formed but a very thin sheet east of the mountains. The base of the formation is a heavy bed of sandstone, which is succeeded by sandstones and shales containing many coal seams. A bed of conglomerate divides the formation in its northward extension, and few coal seams are found in the lower part. In the south the thicker seams are in the lower part. The greatest thickness occurs in the mountains and on Elk river in eastern British Columbia. Near Banff in Alberta the thickness is about 3,700 feet (1,127 m.). In the Bighorn basin this thickness continues. Eastward at Moose mountain it is only some 375 feet (114 m.). The fossils of the formation are plants, such as ferns, cycads, and conifers.

Dakota.—In the mountains above the coal bearing formation, occurs a series of conglomerates and sandstones that is not distinctly coal bearing, although thin coal streaks occur in it. Fresh water conditions prevailed in the mountain section and on the eastern margin during this period of deposition. In the lower part of Athabaska valley, the upper beds at least contain marine fossils.

The thickness of the formation in Manitoba cannot be much more than 200 feet (61 m.). In the foothills a thickness of 950 feet (290 m.) seems to represent the whole formation; but, westward in the Elk river escarpment, a shore deposit thousands of feet in thickness occurs at this horizon.

Benton.—Dark grey, almost black, shale of marine origin, forms a continuous sheet probably across the whole interior basin. In Manitoba the deposit is about 175 feet (53 m.) in thickness. In the foothills it is over 700 feet (213 m.), but this undoubtedly includes part of the overlying Niobrara. The entombed forms of animal life include *Inoceramus problematicus*, *Scaphites ventricosus* and *Prionscyclus woolgari*.

Niobrara.—In Manitoba, this formation consists of grey calcareous shales, which are an upward continuation of the Benton. Westward it is not so characterized in the marginal deposits there, since a period of unrest in the mountains occurred about that time accompanied by brief retreats of the shore line due to a slight rising of the crust. The formation is from 130 to 200 feet (40 to 61 m.) thick in the eastern part. The presence of foraminifera is a characteristic feature of the formation. The fossils include *Serpula semicoalita*, *Ostrea conjesta*, *Anomia obliqua*,

Inoceramus problematicus, *Belemnitella manitobensis*, *Loricula canadensis*, *Ptychodus parvulus*, *Lamna manitobensis*, *Enchodus shumardi*, and *Cladocyclus occidentalis*.

Pierre.—Marine deposits with little trace of calcareous matter succeed the Niobrara. In places almost 1,000 feet (304 m.) of shales are found in the formation. It is claimed that in the western part a great uplift occurred during the early part of this time interval, and brackish and fresh water deposits were formed and afterwards covered by marine beds before the close of the period. In Manitoba the marine sediments are divided into an upper or Odanah and a lower or Millwood. The time interval between the two may coincide with the period of uplift in the west. The western section is divided into *Bearpaw shales*, *Belly River series and Claggett shales*.

Claggett.—The "lower dark shales" of Dawson in southern Alberta have been given a thickness of 800 feet (243 m.). In Moose Mountain 250 feet (76 m.) of shale is supposed to represent this division. They are marine in origin and hold fossils of Pierre type.

Belly River.—This series of shales and sandstone beds are light-coloured and in appearance very much like the beds at the top of the Cretaceous. The fossils are brackish water types with probably fresh water forms in the upper part. Land conditions prevailed toward the close of this period of deposition and coal seams were formed. The measures extend eastward from the vicinity of the mountains into Saskatchewan. The thickness of the formation is about 800 or 900 feet (243 or 274 m.), but probably thins eastward. A similar series on the Peace river—the Dunvegan sandstones—probably belongs to this period.

Bearpaw.—The Pierre-Foxhill of Alberta and Saskatchewan is without doubt the equivalent of the Bearpaw of Montana. The formation in Alberta is about 700 feet (213 m.) in thickness. The fossils are marine and comprise among the common forms, *Baculites compressus*, *B. grandis*, *Scaphites nodosus*, *Placenticeras placenta*, *Inoceramus altus*, *I. nebrascensis*, *I. tenuilineatus*, and many others.

Edmonton.—In southern Saskatchewan the beds formerly called Laramie are divisible into a lower brackish water series and an upper fresh water one. The lower bears the same relation to the upper that the Edmonton does to the early Tertiary.

In southern Alberta the formations above the marine Cretaceous are divided in three subdivisions, the lowest of which at least forms part of the Edmonton division of northern Alberta. This is the brackish water portion of the formation, so called Laramie, and is generally placed at the top of the Cretaceous. The upper limit, the top of the coal horizon, may in time be considered Tertiary. The fossils consist of Dinosaurian remains, with land plants, and the following brackish water animal remains: *Ostrea glabra*, *Unio danae*, *Corbicula occidentalis*, *Panopæ simulatrix* and *P. curta*. The thickness of the formation varies but attains a maximum of 700 feet (213 m.) in central Alberta.

TERTIARY.

Paskapoo.—This series consists of fresh water deposits generally of yellowish sandstones and bluish grey and olive sandy shales. It embraces the upper part of the Laramie of southern Alberta and Saskatchewan, with a total thickness in western Alberta of 5,700 feet (1737m.). The remains of plants are numerous in it and denote a flora of a temperate climate. Fresh water fossils include: *Unio danæ*, *Sphaerium formosum*, *Limnæa tenuicostata*, *Physa copei*, *Acroloxus radiatulus*, *Thaumastus limnæiformis*, *Goniobasis tenuicarinata*, *Campeloma productus*, *Viviparus leai*, *Valvata filosa*, and *V. bicincta*.

Oligocene.—Isolated exposures of coarse grained material, deposited on the Paskapoo representative of the Tertiary in Saskatchewan, have been found to contain a considerable number of Mammalian bones. These beds are characterized by a great quantity of waterworn pebbles derived from the quartzites of the Rocky mountains.

ANNOTATED GUIDE.

Miles and Kilometres.

0 m.
0 km.

Winnipeg—Altitude 760 ft. (231 m.). The capital of Manitoba, population 130,000. The character of the country passed through east of this city shows a gradual change from the hilly surface of the Pre-Cambrian shield to an apparently level plain. This is the lake bottom of a former lake of Glacial time called

Miles and Kilometres.

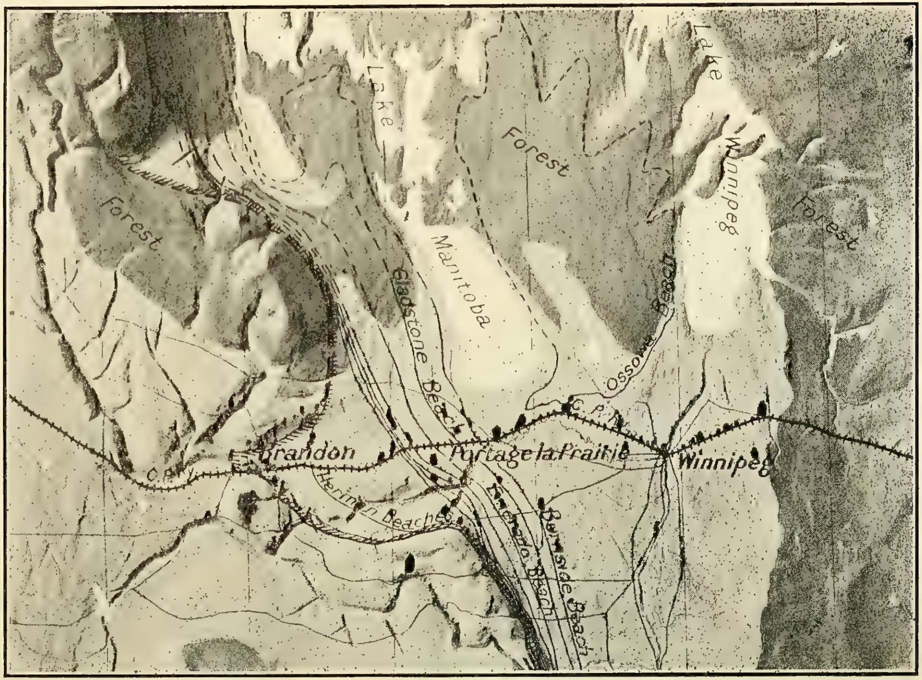
Lake Agassiz. The sediments at the south end of this basin were brought in very rapidly by a strong system of drainage across the Cretaceous plateau to the west, and the erosion of the soft rocks of that region provided abundant material for filling inequalities in the rock surface forming the bed of the lake. At its highest stage Lake Agassiz extended southward to Lake Traverse in Minnesota and drained to the Mississippi valley. At Winnipeg, the depth of water was about 560 feet (170 m). Beaches along the western margin were formed at several stages of the lake recession and these show an upwarping of the crust. A vertical projection of the beaches accompanying this description shows graphically the amount of this movement. The subsidence of the lake, with the retreat of the ice barrier to the north-east, did not at once alter the direction of drainage, and the southward flow was maintained for several stages owing to the upwarp to the north. An outlet northward was found while the water was 240 feet (73 m) deep over the position now occupied by the city of Winnipeg.

In going westward from Winnipeg the rise is very slight across the lower part of the old lake basin, and, since the railway ascends to the rim of the basin on the delta of the principal stream tributary to the lake, beaches are not strongly in evidence. These are however strongly marked both to the north and south and are indicated in the accompanying illustration.

55 m. **Portage la Prairie**—Altitude 851 ft. (259 m).
88 km.

62 m. **Burnside**—Altitude 869 ft. (265 m.).
100 km. Shortly after passing Portage la Prairie the railway crosses a succession of beaches of the ancient glacial Lake Agassiz: the Burnside beach four miles west of Portage la Prairie, and the Gladstone beach two miles (3.2 km.) beyond Burnside near Rat creek.

70 m. **Bagot**—Altitude 936 ft. (285 m.).
112 km.



Plan of beaches of Lake Agassiz in Manitoba.

Miles and Kilometres.

77 m. 124 km. **MacGregor**—Altitude 956 ft. (291 m.). At the 69th mile post, or about two miles (3.2 km.) west of Bagot, is the Emerado beach, and one mile (1.6 km) west of MacGregor the lowest of the Blanchard beaches is crossed.

84 m. 135 km. **Austin**—Altitude 1,015 ft. (309 m.). When the level of Lake Agassiz stood about the level of Austin its drainage changed from flowing southward into the Mississippi and found an outlet northward to Hudson bay.

105 m. 169 km. **Carberry**—Altitude 1257 ft. (383 m). Beaches marking a higher stage in the level of the lake are crossed by the railway before reaching this point, but they are indistinct and not well marked. They may however be found at the following points: at 86.9 miles (27 km.) from Winnipeg is the lower Campbell beach; at 87.5 miles (26.6 km) the upper Campbell beach. Immediately west of Carberry the Herman beaches are to be seen.

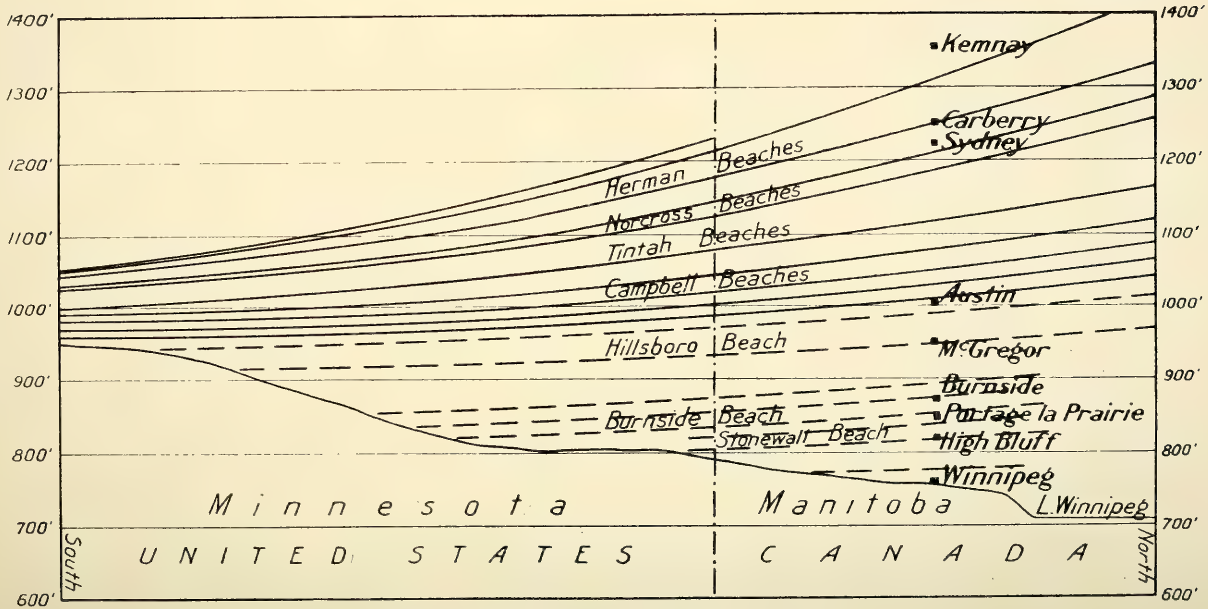
132 m. 212 km. **Brandon**—Altitude—1199 ft. (365 m.). The evidences of Lake Agassiz are very slight at Brandon and as it is situated on the estuary of the ancient Assinboine river at the highest stage of the lake, delta deposits only can be found.

157 m. 253 km. **Griswold**—Altitude 1421 ft. (433 m.). Slight evidences of morainic material occur between Brandon and Griswold which mark the position of the ice front when glacial Lake Souris was in existence. This lake had not the dimensions of Lake Agassiz. It drained southward by the Pembina river.

264 m. 425 km. **Broadview**—Altutude 1961 ft. (598 m.).

356 m. 573 km. **Regina**—Altitude 1884 ft. (564 m.). Regina is the seat of government for the province of Saskatchewan and is situated on a level plain near the western edge of the second prairie steppe.

398 m. 640 km. **Moosejaw**—Altitude 1766 ft. (53 8m.). To the south and west of Moosejaw the low rounded



Projection of beaches of Lake Agassiz in vertical section.

Miles and Kilometres.

hills of the Coteau can be seen rising somewhat abruptly from the level prairie. These hills are the erosion remnants of Tertiary deposits. South of Moosejaw are exposures of white silts and clays, and important deposits of fire clay. Coal seams also occur in these measures.

424 m. 682 km. **Mortlach**—Altitude 1975 ft. (602 m.). The cuttings along the railway here show deposits of boulder clay in irregular shaped hills. Small pebbles occur in the clay, and large boulders appear at the surface.

433 m. 697 km **Parkbeg**—Altitude 2062 ft. (628 m.). The ascent to the third prairie steppe is made through a gap in the hills of the Coteau, and glacial drift is much in evidence which, however, here shows an admixture of material derived also from the underlying sandy beds. Six miles (9.6 km.) west of Parkbeg the boulder clay encloses a body of sandstone evidently removed from the rocks beneath. Morainic material is spread all along the eastern face of these hills, and it is still an open question whether the drift farther west was deposited by floating ice or by a farther advance of the glacial ice front.

508 m. 817 km. **Swift Current**—Altitude 2,420 ft. (736 m.). Beyond Parkbeg the railway follows the plain which slopes northward from Cypress hills and which is underlain by rocks belonging to the Pierre division of the Cretaceous. At Forres station the Belly River

612 m. 985 km. **Forres**—Altitude 2,465 ft. (751 m.).

series comes to the surface, and the rocks of which it is composed outcrop in the hillsides all the way to Medicine Hat. Sections of these rocks are best seen at Redcliff on the north side of the valley of South Saskatchewan river. Near the town and to the east of it the river banks show a great thickness of till.

656 m. 1,056 km. **Medicine Hat**—Altitude 2,168 ft. (661 m.). Natural gas has been found in the lower part of the Belly River series and also in the sandy beds of the continuation of the Dakota. At

Miles and Kilometres.

Medicine Hat the supply is all drawn from depths between 400 (122 m.) and 1,000 feet (304 m.). Gas for various manufacturing processes and power, as well as for heat and light, is available. The city has several wells 1,000 feet (304 m.) in depth with a pressure of 560 pounds capped. Three of these are capable of furnishing 5,000,000 cubic feet of gas per twenty-four hours. Gas is also supplied by several privately owned wells. One owned by the Canadian Pacific railway supplies their shops with 1,250,000 cubic feet per twenty-four hours.

662 m. **Redcliff**—Altitude 2,428 ft. (740 m.). Brick
1,065 km. and other clay products are manufactured at this point at two separate plants, and the burning is done by natural gas. The clay used is from the Belly River formation. To the south the Cypress hills are in view.

Between this point and Calgary the Canadian Pacific Railway company has undertaken to irrigate a large area of farm land, drawing water through large irrigation ditches from the Bow river at Calgary and Bassano.

722 m. **Brooks**—Altitude 2,476 ft. (755 m.). The
1,162 km. top of the Belly River formation is reached at this station. To the west the Rocky Buttes rise in a line of hills marking the eastern edge of the sandy deposits of the top of the Cretaceous. The dark shales of the Pierre (the Bearpaw of Montana) underlie the country to Bassano.

745 m. **Bassano**—Altitude 2,584 ft. (788 m.). The
1,213 km. eastern edge of the Edmonton series is crossed near Bassano. To the south is the valley of Bow river.

762 m. **Crowfoot**—Altitude 2,698 ft. (822 m.). Coal
1,226 km. seams occur in the valley at this place and are mined to some extent by the Blackfoot Indians. These Indians hold in reserve a large block of land to the south of the railway, and the government maintains an agent at Gleichen to teach them farming and to oversee the providing of food and clothes for the aged.

Miles and
Kilometres.

816 m.
1,313 km.

Langdon—Altitude 3,289 ft. (1002 m.). Important towns have grown up along the railway as the result of the irrigation of this section by the Canadian Pacific Railway company.

836 m.
1,345 km.

Calgary—Altitude 3,425 ft. (1044 m.). This fast growing city is becoming a railway centre and manufacturing town. Tertiary rocks of the Paskapoo series, outcrop in this vicinity and are quarried for building stone.

859 m.
1,382 km.

Cochrane—Altitude 3,748 ft. (1142 m.). Here the railway line follows closely the valley of Bow river, which cuts through the sandstones of the Paskapoo series. At Cochrane the beds dip east and form part of the great syncline occupied by Tertiary rocks. The underlying coal-bearing beds are brought up to the surface and at Radnor a seam in the Belly River formation is being mined. Many flexures and folds occur between this point and the mountains.

890 m.
1,432 km.

Kananaskis—Altitude 4,218 ft. (1285 m.).

In the hills immediately north of this station, limestones of the top of the Cambrian have been overthrust on Cretaceous of the Belly River formation.

893 m.
1,437 km.

Exshaw—Altitude 4,247 ft. (1294 m.). Cement manufacturing is the principal industry at this point and the plant is one of the largest in Canada. Limestone is quarried from the mountain side, but shale is now being brought from near Laggan.

903 m.
1,453 km.

Canmore—Altitude 4,283 ft. (1305 m.). This town is situated on the western edge of one of the wide fault blocks from which a great section of Lower Cretaceous has been eroded in the formation of the valley. Southward along the mountain front remnants of these

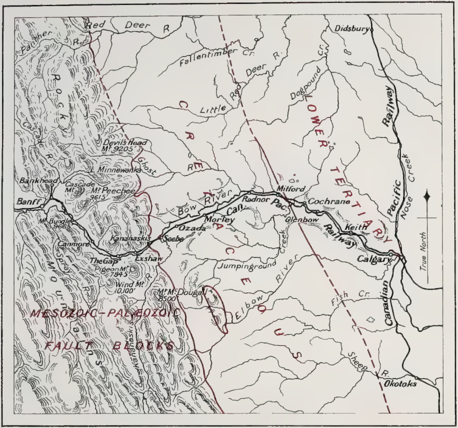
Miles and Kilometres.

beds occur. A narrow westerly dipping fringe of the coal bearing beds is being mined below the surface at this point. Behind the town, cliffs of Devonian and Carboniferous limestones show the eastern edge of the succeeding fault block.

916 m. **Bankhead**—Altitude 4,569 ft. (1393 m.).
1,474 m. In front of Cascade mountain the continuation of the coal measures forms a buttress in which the beds dip towards the fault line. Mining is carried on by an entry driven from the valley level. The cross-cut tunnel from this entry cuts the measures and intersects several seams.

The measures in which these seams occur constitute a block dipping to the southwest toward Cascade mountain. At the south end of the block they pass under the limestone. At the north end, up Cascade river, the measures are bent up in a syncline, but further on they have been entirely eroded away.

A section measured near the mine at Bankhead gives a total thickness of 2,800 feet (853) of possibly coal bearing rocks, with 550 feet (167 m.) of thin bedded brown sandstones and shales above them. The measures consist of sandstones and shales of a generally brown colour, and, in this vicinity, three of the heavy sandstone beds form strong ribs. The upper and lower sandstone ribs seem to define the upper and lower limits of the coal formation, which has a thickness of 1,100 feet (335 m.). Below is a series of sandstones and shales very similar to those higher up. The passage to the Fernie shales is conformable, and is marked by an absence of sandstone. The Fernie shale consists of 1,360 feet (445 m.) of dark grey to black shale overlying 240 feet (73 m.) of dark greyish thin-bedded sandstone, the whole of marine origin and assigned to the Jurassic period. These beds are exposed on the river sides above the mine.



Geological Survey, Canada

Route map between Calgary and Banff

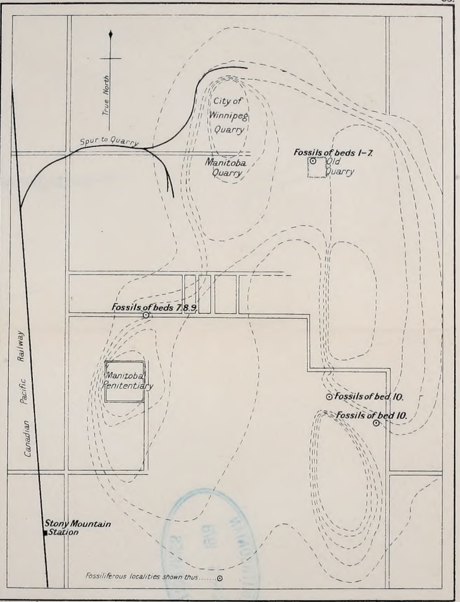
Miles
5 0 10 20 30 40

Kilometres
5 0 10 20 30 40 50 60

The following tabular statement shows the thickness of the coal seams and associated beds and their succession:—

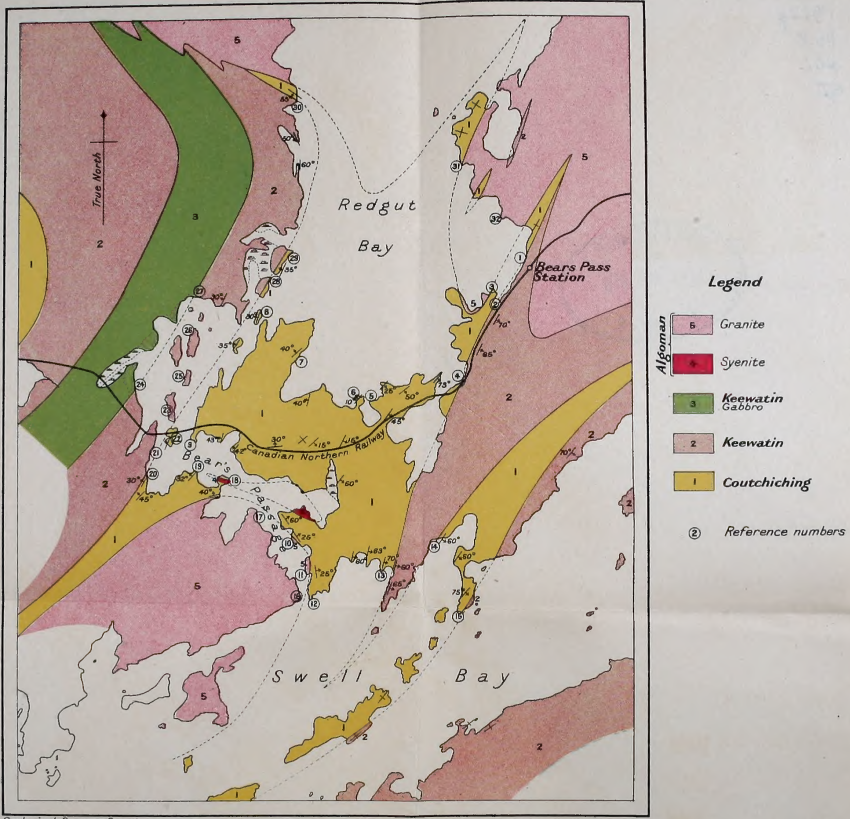
	Feet.	Inches.	Metres.
Seam No. 0.			
Thickness between roof and floor......	5	9	1·7
Coal..................................	3	0	·9
Thickness between No. 0 and No. 1....	33	....	10·0
Seam No. 1.			
Thickness between roof and floor......	12	0	3·6
Coal in thin bands...................	7	11	2·4
Thickness between No. 1 and No. 2....	30	....	9·1
Seam No. 2.			
Thickness between roof and floor......	18	0	5·5
Coal (one clean part, 8 ft.)...........	10	11	3·3
Thickness between No. 2 and No. 3....	92	....	28·0
Seam No. 3.			
Thickness between roof and floor......	29	6	8·9
Coal (two benches 14 ft. and 5 ft.).....	19	....	5·8
Thickness between No. 3 and No. 4....	150	....	45·7
Seam No. 4.			
Thickness between roof and floor......	17	3	5·25
Coal (in three benches 6 ft., 3 ft., 4·5 ft.)	13	6	4·1
Thickness between No. 4 and No. 5....	60	....	18·3
Seam No. 5.			
Thickness between roof and floor......	12	3	3·7
Coal (in the top part)................	6	....	1·8

Pocket contains
2 items



Geological Survey, Canada

Stony Mountain



Geological Survey, Canada.

Bears Passage, Rainy Lake

Miles: 1 ¾ ½ ¼ 0 1 2

Kilometres: 1 ¾ ½ ¼ 0 1 2 3 4